B. E. STECHBART

OLUME XXVII NUMBER ONE

JOURNAL

of the

SOCIETY OF MOTION PICTURE ENGINEERS

S M P E

JULY, 1936

LISHED MONTHLY BY THE SOCIETY OF MOTION PICTURE ENGINEER

FALL CONVENTION

Society of Motion Picture Engineers

Sagamore Hotel

Rochester, N. Y.

October 12th to 15th, Inclusive

Technical Sessions

On the Roof of the Sagamore Hotel and at the plants of the Eastman Kodak Co. and the Bausch & Lomb Optical Co.—Symposiums, General Discussions, Lectures, Demonstrations, Open Forums.

Semi-Annual Banquet

Wednesday evening at Oak Hill Country Club—Dining, dancing, music, entertainment, addresses by eminent members of the industry.

Hotel Rates

Minimum rates and excellent accommodations guaranteed to members: Single, \$3.50 per day; double, \$6.00 per day; parlor suites, double, \$10; parlor suites, triple, \$12.00 per day. Make reservations as early as possible to assure satisfactory accommodations.

Program

See page 120, this issue of the JOURNAL.

Papers for the Fall Convention

Manuscripts of papers received before August 20th will be given immediate consideration by the Papers Committee and the Board of Editors. The best of these manuscripts will be selected and given preferred positions upon the program of the Convention, with ample time for presentation and discussion, or about thirty minutes to one hour. The remaining manuscripts will be considered for the program, but with limited time for presentation.

The remainder of the program will be filled as manuscripts are received, until September 20th, after which date no papers will be accepted unless the subject matter contained therein is particularly outstanding or timely. Titles and abstracts of all papers will be published in the October issue if received by September 1st.

JOURNAL

OF THE SOCIETY OF

MOTION PICTURE ENGINEERS

Volume XXVII JULY, 1936 Number 1

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JOURNAL
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Subscription to non-members, $8.00 per annum; to members, $5.00 per annum, included in their annual membership dues; single copies, $1.00. A discount on subscriptions or single copies of 15 per cent is allowed to accredited agencies. Order from the Society of Motion Picture Engineers, Inc., 20th and Northampton Sts., Easton, Pa., or Hotel Pennsylvania, New York, N. Y.

Published monthly at Easton, Pa., by the Society of Motion Picture Engineers.

Publication Office, 20th & Northampton Sts., Easton, Pa.

General and Editorial Office, Hotel Pennsylvania, New York, N. Y.

Entered as second class matter January 15, 1930, at the Post Office at Easton, Pa., under the Act of March 3, 1879.

See p. 113 for Technical Committees

PROGRESS IN THE MOTION PICTURE INDUSTRY

REPORT OF THE PROGRESS COMMITTEE*

Summary.—*This report of the Progress Committee covers the year 1935. The advances in the cinematographic art are classified as follows: (I) Cinematography; (II) Sound Recording; (III) Sound and Picture Reproduction; (IV) Film Laboratory Practice and Sensitometry; (V) Publications and New Books; Appendix A—General Field of Progress of the Motion Picture Industry in Great Britain; Appendix B—General Field of Progress of the Motion Picture Industry in Japan.*

INTRODUCTION

The Committee believes itself very fortunate this year in being able to collect a great deal of material representing new advances in equipment and in the art of cinematography. It is to be expected, of course, that a great many items that should find their way into a report of this nature will be missing; this can not be attributed to any dereliction on the part of the Committee members, but rather to the inability of the interested parties to supply the Committee with information to be included in the report.

As is noted in the body of the report, color photography made great strides during the year with the introduction of Kodachrome in the amateur field and the extensive use of Technicolor in feature productions.

The advent of the long-awaited silent camera seemed to come nearer in 1935, and descriptions of new silent and nearly silent cameras are contained in the following report of the Committee.

Another item of interest partially developed during the year is the new high-pressure air-cooled and water-cooled mercury arcs which threatened to revolutionize the art of stage and screen lighting, and incidentally offered a new tool for recording sound. It is to be expected that considerable progress will be made by the various branches of cinematography in adopting these arcs during 1936.

In the field of sound recording, considerable progress is to be noted during the year just closed. Push-pull recording gained a strong foot-

* Presented at the Spring, 1936, Meeting at Chicago, Ill.

hold in Hollywood and promises to play an important part in studio production work during the coming year. Invalidation of the Tri-Ergon patents has led to the development of new sound reproducing systems utilizing principles previously barred by the claims of the now defunct patents.

Advancement in sound reproduction was made during the year with the introduction of the new multicellular, or Fletcher, type of horn, which was used so successfully in the binaural transmission of orchestral music between Philadelphia and Washington.

The Committee is glad to include in the report items from Germany and an excellent report of progress in Japan and Great Britain, in which latter country considerable progress has been evident during the past year. The Committee wishes to thank the following firms for supplying materials and photographs for the report: Bell & Howell Company; Electrical Research Products, Inc.; General Radio Company; Mitchell Camera Corporation; RCA Manufacturing Co.; Mole-Richardson, Inc.; Technicolor Motion Picture Corporation; Twentieth Century-Fox Films, Inc.; Fearless Camera Company; Klangfilm, G. m. b. H.

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Subject Classification

(I) CINEMATOGRAPHY

(*A*) *Professional*

(1) Films and Emulsions
(2) Cameras and Accessories
(3) Lenses and Shutters
(4) Stage Illumination
(5) Color

(*B*) *Amateur*

(1) Films
(2) Cameras
(3) Projectors
(4) 16-Mm. Sound Printer
(5) Projectors
(6) Color
(7) Miscellaneous Equipment

(II) SOUND RECORDING

(1) General
(2) Recording Equipment
(3) Re-Recording and Playback Equipment
(4) Testing and Miscellaneous

(III) SOUND AND PICTURE REPRODUCTION

(1) Sound Equipment
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APPENDIX A

General Field of Progress in the Motion Picture Industry in Great Britain.

APPENDIX B

General Field of Progress in the Motion Picture Industry in Japan.

(I) CINEMATOGRAPHY

(*A*) *Professional*

(*1*) *Film and Emulsions.*—The introduction of Kodachrome film in April, 1935, marked one of the greatest achievements of the emulsion manufacturer and research chemist. Although available only in 16-mm. width, the significance of the emulsion makers' skill is nevertheless supreme, because this product requires no less than five separate coatings besides the anti-halo coatings upon the back. During reversal development, the silver image in each emulsion is transformed into a dye image complementary in color to the color to which the emulsion was sensitive. The high sensitivity of the emulsions, necessitating only a slight increase of exposure over that required for ordinary photography, is another useful property of this new color process.[1]

Besides this noteworthy contribution in the field of color, further improvement in negative emulsions was evidenced by the introduction of emulsions of still greater speed than had been available before 1935. These new materials of satisfactory color-sensitivity and low graininess quickly found application both in the studio and for news photography under poor lighting conditions.[2]

Of theoretical interest were the studies made of the effect of using

ultrasonic vibrations in connection with the preparation of emulsions. Claus described an improved method of optical sensitizing which consisted in dyeing the silver bromide (free of carrier) and then dispersing it in the gelatin by ultrasonic waves.[3] It was found by Dangers that the quality of emulsions peptized by ultrasonic waves

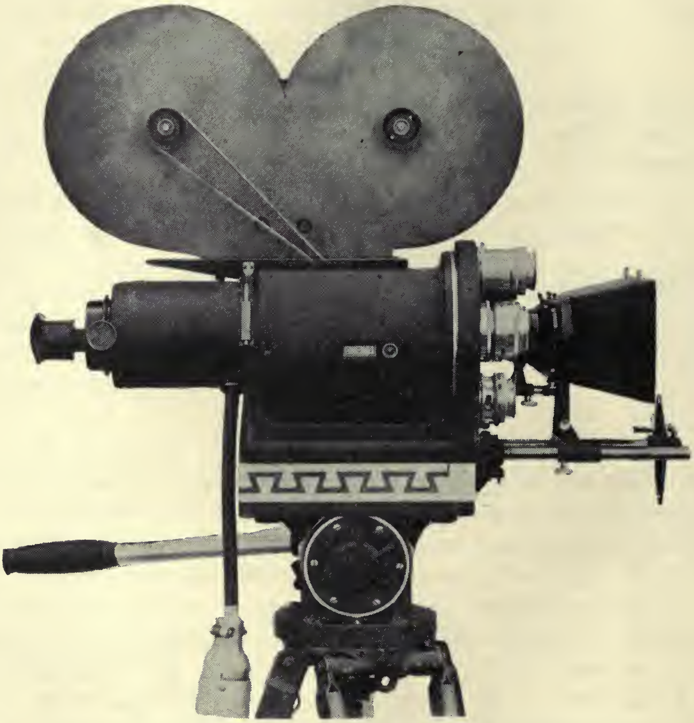

FIG. 1. Silent camera (*Twentieth Century-Fox Film Corp.*).

depended upon the nature of the surface of the silver halide grains upon the addition of the gelatin solution.[4]

A further paper on emulsion technic was published by Fuchs, which described the control of grain size by crystallization inhibitors, the use of dialdehydes to control physical hardening, and the addition of fog-clearing amines.[5]

Summaries were given of the progress made in Russia in photographic research and in the manufacture of photographic materials. While the volume of production had greatly improved, the quality of

the film support and the emulsions was not as satisfactory as had been expected.[6] Subjects discussed by Russian investigators included, among others: (*1*) the influence of acid substrata upon photographic properties; (*2*) the effect of *p*H upon hypersensitization with am-

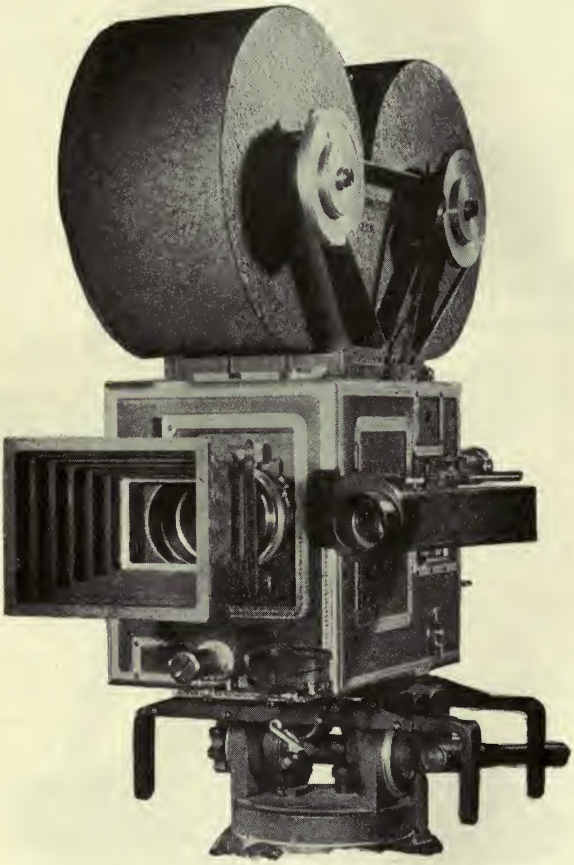

FIG. 2. Technicolor three-color camera (*Technicolor Motion Picture Corp.*).

monia and various buffer solutions; (*3*) the influence of replacements of groupings in thiocyanine dyes upon their usefulness as optical sensitizers.

Loss of sensitivity resulting from bathing various types of photographic emulsions in water before exposure for different times was

reported by Charriou and Valette, who found that the loss of red sensitivity was half that of blue for a panchromatic material.[7]

The chemistry of the cyanine dye series was dealt with extensively

FIG. 3. New studio camera (*Mitchell Camera Co.*).

by Brooker and his co-workers in a group of six papers.[8] A paper was published also by Brooker and Keyes upon new sensitizers for the infrared, which described the preparation of tetra- and penta-carbo-cyanines.[9]

(2) *Cameras and Accessories.*—Perhaps this year's most interest-

ing announcement[10] in professional camera design was made by the technical staff of the Twentieth Century-Fox Film Corporation (Fig. 1). The general layout of the camera developed by this company adheres essentially to conventional American practice; that is, a four-lens turret is used, a durable metal box houses the camera mechanism itself and is surmounted by a dual external film magazine of 1000-ft. capacity, while the driving motor is mounted at the rear. Access to the mechanism is through a door on the left-hand side,

FIG. 4. Panoram dolly (*Fearless Camera Co.*).

at which side is mounted also a finder interlocked with the focusing mechanism.

The camera housing is cylindrical, which shape is best suited to the rotating focusing shift employed. The rotation brings the focusing microscope into place between the lens and a fixed eyepiece at the rear. A conventional, but carefully balanced disk type of shutter is used, having an aperture of 200 degrees.

The film-propelling mechanism employs registering pilot pins, and the motion of the driving pins and their characteristic of straight-line engagement and disengagement and uniform acceleration have permitted reducing the period of take-down while still maintaining desirable uniformity of motion.

Silence is achieved by this uniformity of action of the movement, by reducing the amount of gearing and the weight of the moving

parts, and by giving to the film as free a path as possible. Magazine noise is minimized by affording the film free passage, and by eliminating contact between the edges of the film and the walls of the magazine. Provision has been made for using a variety of standard driving motors. The mounting of the finder is of the conventional form, interlocking with the lens-focusing mechanism to correct for focus and parallax. Parallax compensation is provided by a lateral movement of the finder lens which may be roughly compared to the sliding front board of a still camera.

A new camera for the three-color Techniclor process[11] has a double film-gate at right angles. At one aperture a supersensitive film for the green negative is photographed; at the other, a bi-pack photographic record is taken, the red-sensitive negative being back of a blue-sensitive film (Fig. 2).

The optical system consists of a specially designed photographic objective and a beam-splitting prism. The filtering action for color-selectivity is provided by suitable green and magenta filters. With regard to outside appearance, the camera is designed upon conventional lines. Provisions have been made for perfect registration of the images and for critical focusing.

The new Mitchell studio camera was designed to meet the needs of the present sound stages for a silent, light-weight, compact, and convenient camera (Fig. 3). The most significant changes are the addition of an automatic dissolve, and the replacement of the four-lens turret by a single lens with bayonet lock. Outside the camera proper the finder has been arranged to focus and parallax automatically in conjunction with changing the lens focus in follow or follow-focus shots. All this mechanism, together with the magazine and motor, and with the exception of the finder and follow-focus mechanism, is in an insulated housing, the function of which is to absorb the sound.

The operating controls are all on the outside, so that it is necessary to open the outer housing only to thread the camera. All other operations, such as focusing, changing the magnification on the focus tube, changing the filters in the focus tube, the hand dissolve and the automatic dissolve, are all accomplished from the outside. The weight of the whole equipment with 1000 feet of film is 135 pounds, which is considerably lighter than the lightest blimp in use. The camera is adapted to use either the Western Electric interlock motors or the regular synchronous motors.

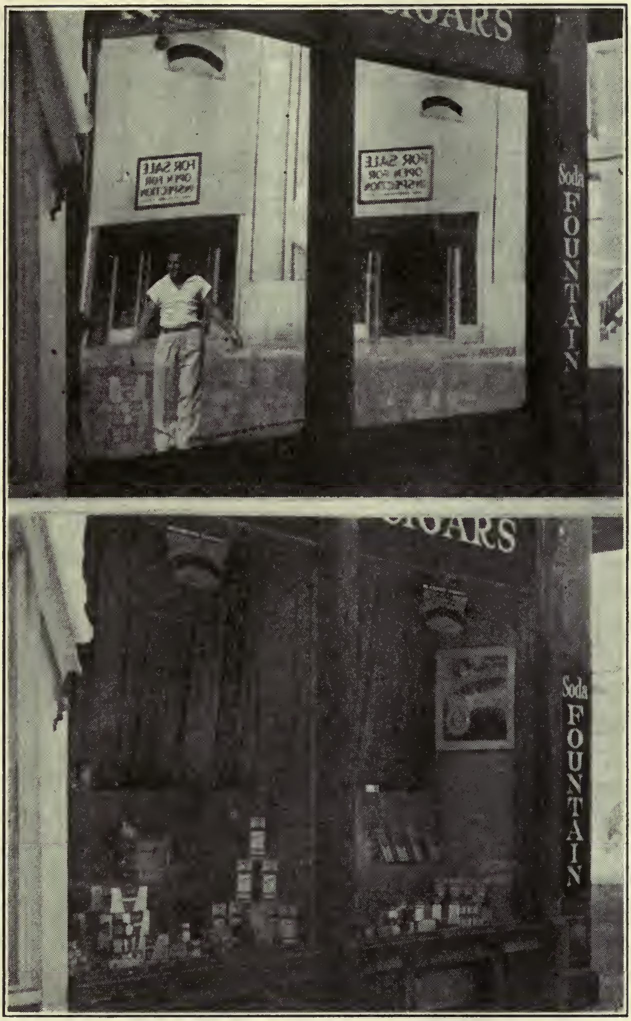

FIG. 5. Elimination of reflections from store window by Eastman Pola-Screen: (*upper*) without screen; (*lower*) with screen.

The Fox-Fearless type of dolly, or velocilator, has found its way into nearly all the larger studios because of its mobility and the ease with which it handles the heavier blimps. A new type of velocilator, made by both Fearless and Raby, carrying the boom arm upon a turntable, is fast becoming popular (Fig. 4). The great improvements

that have been made in such devices will no doubt make them an accepted part of every camera equipment, replacing tripods except for special shots, even when cameras return to their pre-sound weights.

(3) *Lenses and Shutters.*—No exceptional advancements have been made in camera lenses during 1935. A faster series of Speed Panchro lenses ($f/1.3$, $2^1/_4$-inch focus) has been put upon the market. Altman has described in the JOURNAL[12] a revolving panoramic lens that has unusual possibilities as a wide-angle lens. A more detailed description of the German mirror telephoto lenses has been published,[13] and there are the usual patents on new or improved forms of lenses.[14]

A very interesting accessory to the optical field is the Pola-Screen introduced by the Eastman Kodak Company. This screen gives the operator a hitherto impossible control of the polarized light entering the lens of the camera, making available several of its peculiar characteristics. The elimination of reflections is now simple, maximum results being attained when the optical axis of the lens is at a 32-degree angle from the reflecting surface, as at that angle the light reflected from most surfaces is fully polarized (Fig. 5). Sky-filtering is possible when the lens axis is at right angles to the sun's rays, which will prove of value in color photography, since the Pola-Screen is of neutral color value.

The Pola-Screen opens up possibilities also in the field of stereoscopy, applying it in a manner somewhat similar to viewing a blue and red positive through corresponding blue and red glasses, but without the color interference. A description of the possibilities of the filters has been published by Tuttle and McFarlane,[15] and DeVinna has written an account of practical experience with these filters in cinematography.[16]

(4) *Stage Illumination.*—The rapid progress made in new types of gaseous conductor lamps during the past year or so continues to be of outstanding interest in the lighting industry as a whole. The laboratories of the Philips Lamp Company of Holland, as well as those of the General Electric Company in the United States, have produced mercury vapor lamps of the air-cooled type having brightnesses of the order of 20,000 candles per square-inch; and of the water-cooled type, about 150,000 candles per square-inch. By way of comparison, the old familiar Cooper-Hewitt mercury vapor tube had a brightness of 15 candles per square-inch, and the high-efficiency incandescent lamp can be operated at brightnesses up to 20,000 candles

per square-inch. These lamps, in general, consists of a quartz tube with electrodes at each end, and are enclosed within a protective housing. The experimental air-cooled lamps had light-sources approximately 4 millimeters in diameter and about 10 millimeters in length. The water-cooled types were slightly smaller. Since they possess the characteristics of an arc, they must be used in conjunction with either a resistor or reactance ballast.

Operating the mercury vapor source at these high brightnesses results in considerable improvement in the quality of the light, but nevertheless the light retains much of its usual blue-green properties. At the present time their application as light-sources for studio motion picture photography appears rather remote, particularly when the severe requirements of color photography are considered. The extremely great brightness of the water-cooled lamp offers possibilities as a projection source.

FIG. 6. 120-ampere spotlight with Fresnel lens (*Mole-Richardson, Inc.*).

Since photography is so dependent upon the source of light, mention should be made of the new Mole-Richardson spotlights for both incandescent and arc lighting. Their 2000-watt Junior and 5000-watt Senior Solar Spots, with Fresnel lenses, provide a uniform field of illumination with no "ghost." This likewise applies to their so-called *Hl* type of high-intensity arc spot, which is especially valuable in color photography and is finding a place in black-and-white photography also because of the reasons mentioned above. Their 120-ampere spot (Fig. 6) has an intensity equivalent to that of the 24-inch Sun arc; and their 150-ampere spot is claimed to equal the 36-inch Sun arc in intensity. In both lamps the beam may be varied from parallel to a 44-degree angle.

(5) *Color.*—The revived interest in color processes noted in

1934 continued throughout 1935, stimulated no doubt by the introduction of the Kodachrome process mentioned earlier in this report. At a symposium on color photography held at the Hollywood Convention in May, Ball described the technical aspects of the Technicolor process. The first three-color, feature-length motion picture was released in June. It was entitled *Becky Sharp*, and was made by the Technicolor imbibition process. The picture was made entirely

FIG. 7. Double-eight model *134A* camera (8-mm.) (*Bell & Howell Co.*).

by artificial light; but a second feature, *The Trail of the Lonesome Pine*, released in the Spring of 1936, was made almost exclusively outdoors.

Technicolor made great advances with their three-color process, with pictures now showing or in production that will no doubt revive color interest in the industry. Good definition, depth of focus, and a conservation of color values make the process the only practical one to date in the 35-mm. field.

A comprehensive paper was published by Gaspar giving a critical

commentary on additive and subtractive processes of photography and details of the entire production and processing of Gasparcolor film. The incorporation of actual dyes (polyazo), instead of esters of vat leuco dyes formerly employed, is claimed to offer the advantage of advance determination of both shade and concentration of the dye. Sensitization of the new material is not complementary, *i. e.*, the yellow layer is green sensitive; the magenta layer, red sensitive; and the blue-green layer, sensitive to the infrared.[17]

Emulsions available for amateur color cinematography included, besides Kodachrome, a screen-coated emulsion known as Dufaycolor and a fine-lined lenticular film called Ultra-Chrome Color Film.[18] A detailed description of the method of preparing the Dufaycolor screens and processing the film was given by Renwick, who states that copies may be produced both by projection and by contact printing.[19] The characteristics and applications of the lenticular screen were treated by Heymer.[20] The same author gives a comprehensive review of color-films by the "Silver-Dye Bleaching" process.[20]

(*B*) *Amateur*

1935 has been an eventful year in the substandard ciné field. It has brought about interesting developments in equipment and processes, and has again demonstrated the tendency of the manufacturer to improve and refine existing equipment. Public interest in amateur cinematography has been stimulated by the introduction of new developments in 8-mm. equipment, and by the improvement in sound equipment and color in the 16-mm. field.

The development of 16-mm. projectors with increased light and adequate sound, capable of serving large audiences, and the general use of fine-grained films are gradually raising the 16-mm. film from strictly amateur use to that of semi-professional. Similar developments in fine-grained film and improvement in equipment have resulted in a general acceptance of 8-mm. film for amateur use.

(*1*) *Films.*—Filmopan, an extremely fine-grained reversible 8-mm. film was produced by Agfa Ansco Corporation for the Filmo straight-eight camera. The film is 8 millimeters wide, and carries perforations on one side in the conventional manner.

(*2*) *Cameras.*—Bell & Howell have entered the 8-mm. field and introduced a straight-eight and a double-eight camera (Fig. 7). Both are designed according to entirely new principles, and offer

the utmost in simplicity of operation. The Filmo straight-eight accommodates 30 feet of straight 8-mm. film, whereas the double-eight takes film of 16-mm. width which is divided into 8-mm. strips after being processed. In the straight-eight there are no sprockets to be laced. Spools are held in the hand, and the film end is quickly engaged through the hub of the take-up spool; both spools are then dropped upon the spindles of the camera without having to check loops, sprockets, or aperture gate. The gate is automatically held open, and closes when the camera door is shut, automatically engaging the shuttle tooth.

The camera incorporates a built-in view-finder with auxiliary masks attached so as to be instantly positioned according to the focal length of the lens used. It is equipped with the 21.5-mm. *f*/2.5 Taylor, Taylor, Hobson lens, and has four film speeds: 8, 16, 24, and 32 frames per second. A special model is also available with speeds ranging from 16 to 64 frames per second. An exposure dial is built into the camera door. Auxiliary lenses are available in focal lengths of 1 and 1.5 inches, and vary in speed from *f*/1.5 to *f*/3.5. An ingenious lens mount is provided which enables the lenses to be changed instantly.

A magazine Ciné Kodak using 16-mm. film has been placed upon the market. It operates at speeds of 8, 16, and 64 frames per second, and has interchangeable telephoto lenses ranging from 1-inch *f*/1.9 to 6-inch *f*/4.5. The eye-level view-finder incorporated in the carrying handle is adjustable to serve all five lenses. A new type of magazine is employed carrying 50 feet of film, either Ciné Kodak panchromatic, Ciné Kodak *SS* panchromatic, or Kodachrome. Each magazine carries its own footage meter and normally is closed. When the magazine is placed into the camera and the camera closed, the film aperture of the magazine is opened. The act of opening the camera after exposure closes the aperture on the magazine. No frames are therefore lost.

(*3*) *Projectors.*—The Ampro Corporation announced a new design in the barrel type of shutter used in their projectors, resulting in a screen brilliancy 90 per cent greater, with the same 750-watt source, than was heretofore possible.

A new model *40* Kodascope *8* was made available to replace the model *25*. This projector utilizes a 200-watt lamp, making possible large screen images and greater brilliancy from 8-mm. film.

A new, heavy-duty, 16-mm. projector for auditorium use has been

announced by DeVry. The outstanding feature of this projector is the incorporation of an intermittent sprocket instead of the more familiar claw to effect the step-motion of the film.

(*4*) *16-Mm. Sound Printer.*—The RCA Manufacturing Company, Inc., developed and furnished to a number of film laboratories processing 16-mm. sound-film an optical reduction printer for making 16-mm. sound-track prints from 35-mm. sound negatives.

These printers were developed in order to make available to the users of 16-mm. equipment sound prints having an extended frequency range and free from flutter or sprocket modulation. The printers do not scan the sound-track to be printed; but, instead, a section of the 35-mm. film is imaged upon the 16-mm. stock. This system eliminates the effect of the width of the light-beam on the 16-mm. film, which in systems in which the scanning is done through narrow slits so that the 16-mm. film is exposed by a thin modulated light-beam, results in distortion and losses at the higher frequencies.

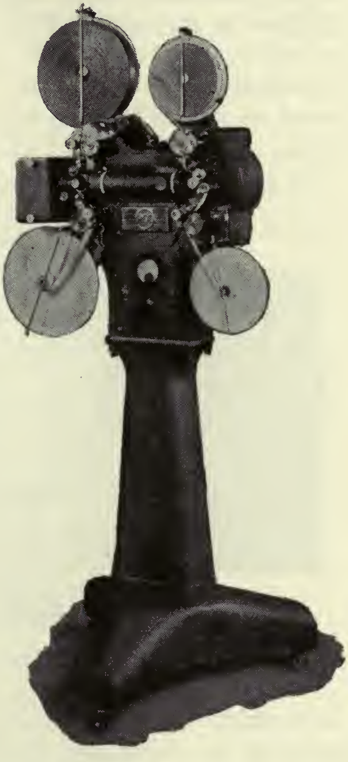

FIG. 8. Optical reduction sound printer (*RCA Manufacturing Co.*).

The printer is shown in Fig. 8. It is driven by a three-phase synchronous motor. The 35-mm. film runs at 90 feet per minute. To insure smooth film motion, a mechanical filter system of the rotary stabilizer type is used.

(*5*) *Sound Projectors.*—The Bell & Howell Company introduced a 1000-watt sound projector (Fig. 9), which incorporates all the features of the silent model, such as provision for 1000-ft. reels and film-conditioning during projection. In addition, the sound model is equipped with a dual amplifier giving an undistorted output of 25 watts and a quality of sound reproduction that has been heretofore unavailable in the 16-mm. field. The amplifier and projector are so

constructed as to permit the use of one or two projectors without changing the internal wiring of any of the components. Voltage adapters are incorporated in the amplifier to compensate for differences in photocells, enabling projectionists to operate either projector without changing the volume control setting. The amplifier is designed to permit the use of a wide variety of microphones, such as carbon, velocity, crystal, or magnetic, without any alteration of the amplifier. The volume control is arranged to permit mixing sound records on the film and adding comments through the microphone.

To popularize 16-mm. sound-film further, Victor Animatograph

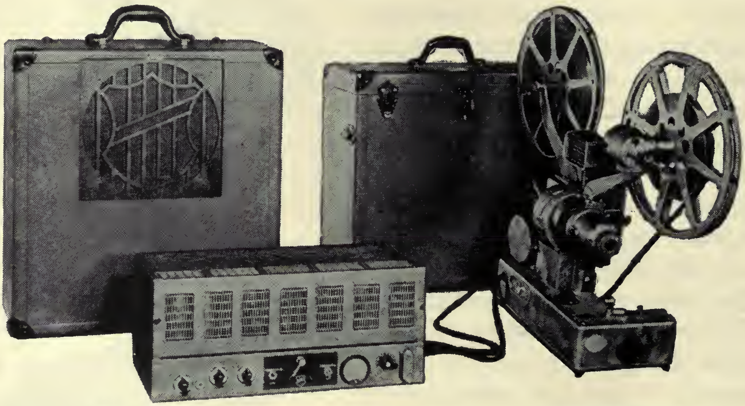

FIG. 9. 1000-watt Filmosound projector for 16-mm. film (*Bell & Howell Co.*).

Corporation has announced the Victor projector, model *25*. In designing this equipment Victor is again pioneering in the development of high-quality but moderately priced sound equipment. This new projector, while not having the power of the model introduced last year, is sufficiently powerful for average school and home use.

Andre Debrie, Inc., have recently introduced in America their new 16-mm. sound projector. This projector has been widely advertised and has been favorably accepted abroad.

Agfa introduced abroad the Movector Super *16* in a new sound model adaptable for either 110 or 220 volts a-c. The projector represents the latest development as to screen illumination and sound reproduction.

The Berndt-Maurer Corporation is now offering complete sound

recording equipment for 16-mm. film, including monitor and microphone, designed to work with a microphone as well as with direct pick-up from an amplifier. The complete unit is very compact.

(6) *Color.*—The outstanding event in the amateur motion picture world during 1935 was represented by the introduction of the Kodachrome Process in April by the Eastman Kodak Company. This is

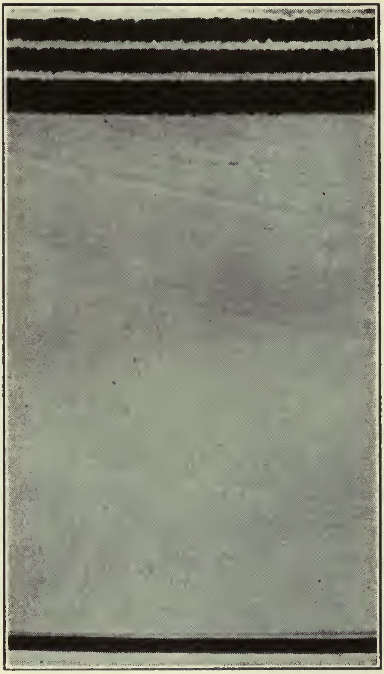

FIG. 10. Cross-section of Kodachrome film (*Eastman Kodak Co.*).

a process of amateur cinematography in colors. It is a three-color subtractive process, the dyed images being incorporated in coatings upon one side of the film. It has an advantage over earlier amateur motion picture color processes in that the image is not broken into small units by screen elements or lenticular embossings.

In the Kodachrome Process the film is coated upon one side with five layers. Next to the support is a red-sensitive emulsion; upon

this, a layer of gelatin; then, a green-sensitive emulsion; then, another layer of gelatin; and upon the top, a coating of blue-sensitive emulsion (Fig. 10). The upper layer carries a yellow screening dye to prevent the blue light from reaching to the two lower emulsions. The film is exposed in any 16-mm. camera at approximately one stop larger than used for black-and-white pictures, without filters or other attachments, and can be run interchangeably with black-and-white film without any appreciable loss in screen brightness.

In processing, the images are developed by a reversal process which converts them into positive dye images that are complementary in color to the spectral regions to which the layers respond. Processing can be done only in the stations of the Eastman Kodak Company. The film is supplied in 50- and 100-ft. spools, and in magazines, and in 16-mm. width only.

(7) *Miscellaneous Equipment.*—A new exposure meter of the photoelectric type was announced by Photo-Utilities. This new photoscope incorporates a mirror to reflect light to the sensitive cell. Greater sensitivity is claimed for this meter. Weston also has announced a new meter having increased sensitivity.

A continuous contact-printer of both silent and sound 16-mm. film has been designed by the Fried Camera Company of Hollywood. The new printer is compact and simple in operation, and a semi-automatic light-change is provided.

Bell & Howell have made 400-ft. magazines available for Filmo *70* cameras. This magazine is identical in construction to the Bell & Howell 35-mm. magazine which has been standard in the professional studios for many years.

(II) SOUND RECORDING

(*1*) *General.*—The past year has been marked by a renewed interest in improving both sound recording and reproduction. The invalidation of the Tri-Ergon patents by the U. S. Supreme Court opened the way for intensive development of sound equipment which had been barred previously by the claims of these patents.

At the S. M. P. E. Convention at Hollywood (May, 1935) a demonstration of push-pull, variable-density recording was given by Douglas Shearer, of the Metro-Goldwyn-Mayer Studios. The sound was projected with the Fletcher two-way horn system previously developed for the binaural transmission of music from Philadelphia to Washington. At the same Convention J. A. Miller demonstrated the

mechanographic method of recording sound upon film. Metro-Goldwyn-Mayer used the push-pull method for all original recording at the studio during the past year, re-recording to standard width track for the release prints.

(*2*) *Recording Equipment.*—RCA announced that several improve-

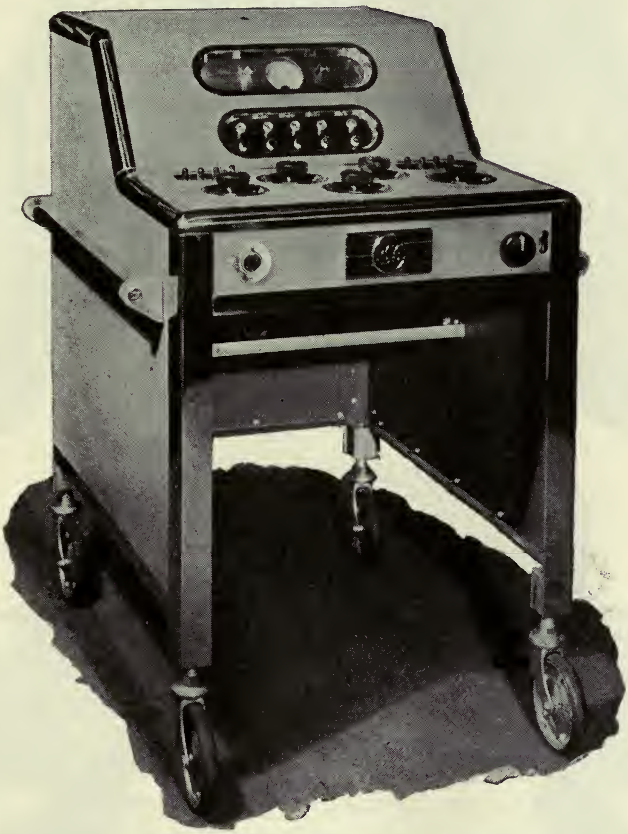

FIG. 11. Sound recording stage dolly (*RCA Manufacturing Co.*).

ments had been made in their studio sound recording equipment during 1935. A light-modulating system was produced and installed in several studios which utilized a beam of light only $^1/_6$ of a mil thick for exposing the film. An improvement in the efficiency of the optical system and a new recording lamp made it possible to realize the increase in high-frequency response and the reduction in distortion.

The recorders are equipped with apertures for either push-pull or single-track recording.

New amplifiers and control equipment have been designed which

FIG. 12. Dolly-mounted portable ERPI recording system: (*a*) front view; (*b*) rear view (*Paramount Productions, Inc.*).

more completely fulfill the requirements for flexibility as to mounting and arrangement for either studio, booth, or truck installations. The mounting racks may be placed against a wall, as all parts are acces-

sible from the front, all panels are hinged so as to open toward the front, and all the parts are mounted upon the panels. The same equipment is suitable for stage mixing with high-fidelity phones (Fig. 11).

Electrical Research Products, Inc., announces a new Western Electric portable recording system. This equipment has been designed with sufficient flexibility to fulfill requirements both in the

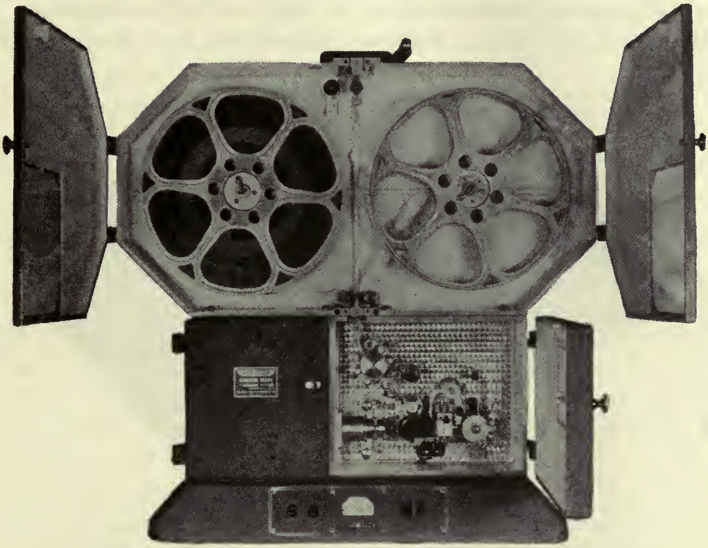

FIG. 13. Re-recording machine (*Electrical Research Products, Inc.*).

studios and on location, and to permit interconnection with existing equipment if desired.

The new items of equipment comprising these stage units of the "tea-cart" or "dolly" type are (*1*) the pick-up unit, which, briefly, consists of the necessary pre-amplification, four mixer positions, and an over-all volume control; (*2*) the main amplifier, providing separate outputs for recording and monitoring; and (*3*) an a-c. power conversion unit, which may be used in lieu of batteries (Fig. 12).

With this arrangement all transmission adjustments are controlled at the stage, the remainder of the routine operations being handled at the position of the recorder, where newly designed units consisting of the recording machine and associated controls for noise reduction

and the motor system are located. Inter-phone equipment is built in, and provision is made for extending this communication circuit to the attendant at the microphone boom. Three microphones of the non-directional type, recently developed by the Bell Telephone Laboratories, may be connected directly to the pick-up unit, and provision is made for a fourth microphone input to operate from a standard microphone amplifier.

The stage unit may be operated as part of a stage booth equipped with loud speaker monitor or in the open, using head-phones. For the latter case, the Bell Telephone Laboratories have made available

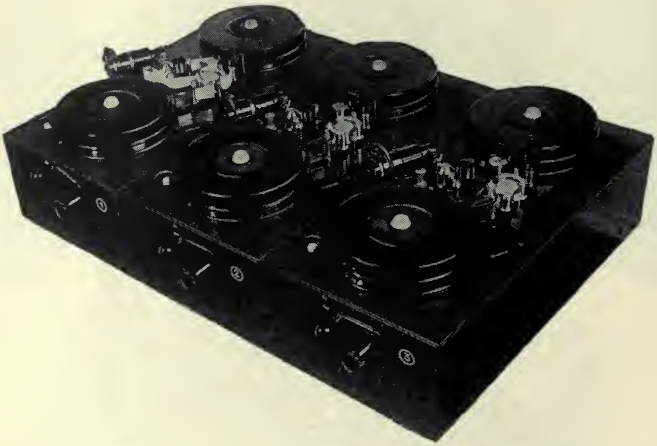

FIG. 14. Three-unit playback (*Klangfilm, G.m.b.H.*).

new high-quality head-phone receivers of the moving-coil type. These receivers have a marked improvement in response at both high and and low frequencies, and thus serve as better critera of the final recorded results than receivers heretofore available.

(*3*) *Re-Recording and Playback Equipment.*—Electrical Research Products, Inc., have announced an improvement in Western Electric re-recording equipment in the form of a new re-recorder for film reproduction (Fig. 13). The machine employs a new type of film-moving mechanism that is comparatively free from flutter, is very stable in operation, and incorporates a number of features contributing to ease of operation and maintenance. It is a self-contained pick-up unit for direct mixer input, as it contains all the necessary features of preliminary amplification as well as film equalization.

It is adapted for use with either half-width or full-width 35-mm. film and sound-tracks of either the standard or double-track, push-pull type, and is provided with an automatic rewind device for convenience in operation. Initial installations of this machine have been at MGM Studios who were instrumental in contributing valuable coöperation from a practical operating standpoint.

From Germany comes announcement of the Klangfilm multiple playback device, which promises to play an important part in playback and re-recording technic. One or more sound-tracks may be played back synchronously, all the units being capable of being interlocked with a projector or a recording machine. The equipment is arranged so that any one of the units may be used alone. An interesting feature is the ability to play back either negative or positive films with the device, the only change being the movement of a simple lever. Another feature is the provision for rewinding the film without removing it from the machine, three rewinding speeds being provided. A view of the triple multiple playback unit is shown in Fig. 14, the whole assembly being constructed horizontally instead of in the usual vertical arrangement of film reproducing apparatus. Provision is made for 300-meter rolls and for film loops up to 100 meters long. The advantages claimed for this multiple playback unit are (*1*) highest quality of sound; (*2*) simplicity of operation; (*3*) no film multilation; (*4*) flexibility of operation.

The scanning system in this playback is similar to that used in the *Europa* sound-film equipment. This movement is said to assure absolutely uniform motion of the film at the scanning point. The movement is illustrated in Fig. 15.

(*4*) *Testing and Miscellaneous.*—With the increased use of portable equipment for use on location and of mobile stage units in recording, Electrical Research Products, Inc., has recognized the need for complete and reliable testing equipment of the portable type. They have consequently produced a combined portable oscillator and transmission-measuring set capable of checking gain, frequency, and power characteristics of complete operating channels or component parts. The oscillator is variable over the range of 40 to 14,000 cps., and the gain set will measure gains up to 120 decibels and losses to 10 decibels. Convenient matching networks are provided to simplify measurements of various types of circuits. The oscillator is useful also for making frequency test-films and for tuning light-valves. The equipment is mounted on a chasis in a single case, the

total weight being 50 pounds, and may be operated with batteries or an associated a-c. power conversion unit weighing 22 pounds.

Electrical Research Products, Inc., is making field trials of a new midget noise meter design coded as the *RA–198* sound level meter, in

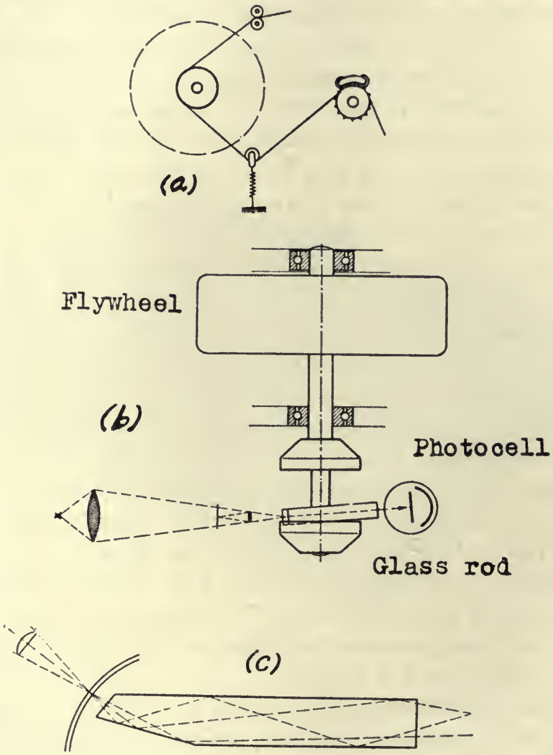

FIG. 15. Scanning system of Klangfilm multiple playback: (*a*) film guiding at scanning point; (*b*) reproducing system, with rotary film-track and glass rod; (*c*) path of the light-beam in the *Europa* equipment.

which compactness and simplicity of operation are the outstanding features. According to present specifications, the outside dimensions will be approximately 6 × 9 × 4 inches. The microphone, of the moving-coil type, is mounted in the face of the instrument, which is intended to be held in the hand when operated. Accurate readings may be made quickly without special skill on the part of the operator. No external power supply or batteries are required. Levels from 40

to 125 decibels on the standard ASA scale may be measured. This range includes everything from quiet street and office noise levels to the loudest noises encountered. The instrument is designed to have a relative response to various frequencies or pitches of sound like that of the human ear.

The General Radio Company has announced several items of

FIG. 16. Strobotac—a portoble stroboscope with neon lamp (*General Radio Co.*).

interest to the sound engineer. A beat-frequency oscillator covers a frequency range of 10 to 20,000 cps. Its power output is 2 watts, maximum. The voltage output is constant over the entire range, and the total harmonic distortion is less than 1 per cent. The oscillator is completely a-c. operated, and can be mounted either in the cabinet furnished or upon a standard 19-inch relay rack. A more complete description is given in the July, 1935, issue of the *General Radio Experimenter.*

The new General Radio distortion-measuring instrument is direct-reading, employing a large pointer-type meter. It operates on a test-signal of 400 cps., and is intended for use also in measuring the noise level of audio-frequency circuits when no audio-frequency signal voltages are present. This instrument is designed for relay rack mounting. Although developed for use in the radio broadcasting

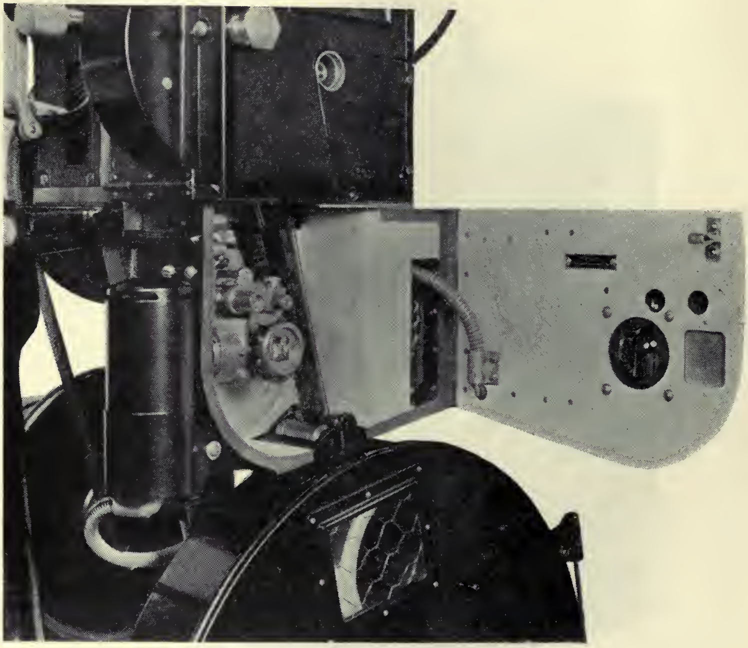

FIG. 17. Type *209* reproducer set for small theaters (*Electrical Research Products, Inc.*).

industry, the distortion and noise meter is applicable to all types of audio-frequency testing.

The General Radio Strobotac is a small portable stroboscope using a neon lamp (Fig. 16). Although designed primarily for rapid speed measurements, it can be used also for the stroboscopic observation of rapidly moving objects. It should prove to be a valuable tool in both manufacturing and servicing motion picture cameras. The larger Edgerton stroboscope, type *548-B*, has been widely used by camera manufacturers. The Strobotac, being a low-priced instru-

ment, may possibly extend the advantages of the stroboscopic technic to servicing cameras and projectors. It will probably be particularly useful in observing irregularities in the operation of sprockets and shutters.

(III) SOUND AND PICTURE REPRODUCTION

(*1*) *Sound Equipment.*—Continued progress was noted during the past year in improvements in sound reproducing systems, attention being given to the film motion and to extending the frequency range of reproduction by the introduction of novel horn designs.

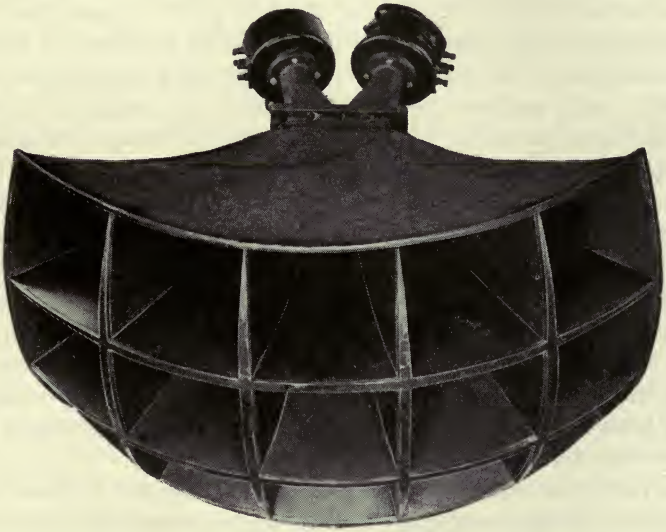

FIG. 18. Multi-cellular horn (*Electrical Research Products, Inc.*).

Electrical Research Products, Inc., has announced a new high-quality reproducer set which forms part of a low-priced system recently announced, and has been designed with particular attention to the requirements of the small theater, high quality, economy, and simplicity being emphasized (Fig. 17).

The type *209* reproducer set, as it is designated, may be attached to the picture projector with unusual ease, as all gears or other forms of drive have been eliminated between the picture mechanism and the sound reproducer. This avoids difficult alignment problems and "shimming." Sprockets are not required in the reproducer set, as the film is propelled only by the sprockets of the projector mechanism.

The new kinetic scanner controls the film motion and prevents flutter. The scanning system includes a prefocused-base exciter lamp, a high-efficiency optical system, and a photoelectric cell of greatly increased sensitivity. A special transformer is included for connecting the reproducer set to the system main amplifier; no amplifier is required at the machine.

The same company has also introduced horns of the "multi-cellular" type, the fundamental principles of which were developed by the Bell Telephone Laboratories. The design known to the industry as the "Fletcher" horn is another great contribution to the art of loud speaker design (Fig. 18). One of the first public demonstrations of this apparatus was given before the National Academy of Sciences in Washington, D.C., on April 27, 1933, during a presentation of the reproduction in auditory perspective of orchestral music by the Philadelphia Orchestra under the direction of Dr. Leopold Stokowski. The music of the orchestra in Philadelphia was reproduced at Washington by means of a special system including the "Fletcher" horns. The system was described by F. B. Jewett at the meeting of the National Academy of Sciences, at Washington, D.C., in April, 1933.[21] Another demonstration was presented at the winter convention of the American Institute of Electrical Engineers at New York on January, 1934, at which time papers were read describing the theory and design of the new loud speakers.[22] The new designs introduced by ERPI have aroused great interest in recent demonstrations of high-quality sound-picture reproduction.

The horns are divided into diverging rectangular sections which distribute the sound uniformly over prescribed vertical and horizontal angles, assuring faithful balance at all frequencies. A new receiver having an efficiency about 100 per cent higher than any unit heretofore produced has also been developed. One to four receivers may be attached to a horn. Special throats are employed for connecting the receivers to the horn; the spaces surrounding the diaphragms of the receivers are specially designed to couple the diaphragms with the air columns of the horn efficiently and without distortion. The total depth of the horn is about 40 inches, thus allowing practical and convenient backstage arrangement.

RCA announces new high-fidelity, a-c. operated reproducers employing the rotary stabilizer form of control, and having increased power output and optional speaker complements to suit the requirements of individual theaters.

(*2*) *Projectors and Accessories.*—The past year has seen a definite trend toward high-intensity projection by theaters of small and intermediate size, replacing the low-intensity reflector arc which has been in almost universal use in theaters of these classes. This change in projection practice has been made possible by the development of the a-c. high-intensity and the Suprex projector carbons, together with improved lamps for their operation. Now that these new carbons and lamps have placed high-intensity projection within economic reach, the smaller theaters are rapidly availing themselves of the advantages already demonstrated in that respect by the large downtown theaters, in which high-intensity projection lamps have been in use for a number of years. The theater-going public has definitely shown its preference for the improved quality of projection light, the superior projection of color features, and the higher level of general illumination that high-intensity projection makes possible.

For some time there has been a demand by a number of the larger theaters for still more intense illumination than could be supplied by the 13.6-mm., high-intensity projection carbon operated at 120–130 amperes. This demand has now been met by the development of a 13.6-mm., super-high-intensity carbon adapted to steady operation over a current range of 140–190 amperes. At the upper limit of current this new super-high-intensity carbon provides 30 per cent more light than the regular 13.6-mm., high-intensity carbon. There is also a more uniform distribution of brilliancy across the face of the crater of the new carbon, resulting in less contrast in screen illumination between the center and the sides or corners of the screen.

The lamp companies have recently made available an 8-volt, 2-ampere *T-8* bulb sound-picture reproducer lamp of improved characteristics (Fig. 19). This lamp, in general, replaces the widely used $8^1/_2$-volt, 4-ampere lamp of similar dimensions. Its low current rating permits operating it on rectifier filter systems of relatively small size and weight. The proportions of the source are such that the lamp operates particularly well with reproducer optical systems incorporating cylindrical lenses as well as with those of the aperture type. The lamp is available with the standard single-contact bayonet base as well as with the new precision prefocus base. The prefocus base makes it possible to position the lamp correctly in the optical system by merely inserting it into its special socket. This is a particularly valuable feature for portable and semiportable equipment when the usual skilled operators are not available. The lamp is

applicable also to a number of 16-mm. sound-picture projectors.

In connection with their studies of various types of recording and reproducing lamps for sound-picture work, the engineers of the Lamp Department of the General Electric Company have developed a special form of microphotometer which makes possible the measurement of brightness distribution across the scanning-beam as well as the total scanning-beam brightness for various types of optical systems and lamps. The General Electric Company has also recently placed upon the market a compact, inexpensive foot-candle meter, which should prove valuable to theater servicing organizations for checking screen and auditorium illumination, *etc.*

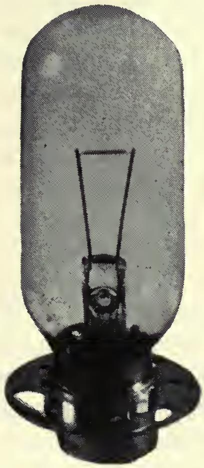

FIG. 19. 8-volt, 2-ampere sound recording lamp (*General Electric Co.*).

Zeiss has brought out a new series of projection objectives for theaters,[23] the focal lengths of which range from 120 to 180 centimeters. The mounts are either 80 or 100 millimeters in diameter.

(IV) LABORATORY PRACTICE AND SENSITOMETRY

Installations of the Bell & Howell production printer in release print laboratories greatly increased in number during the past year. The RCA Manufacturing Company announces successful introduction of their 35-mm. to 16-mm. reduction sound printers in a number of laboratories during the year. There is not much to report in the way of new practices or equipment in the field of sensitometric control.

The Ninth International Congress of Scientific and Applied Photography was held at Paris, July 7 to 13, 1935, in the meeting rooms of the French Photographic Society. The organization of the Congress was undertaken by a Committee appointed by the French Photographic Society, and included representatives of photographic, scientific, and technical bodies from many countries.[24]

The two problems that gave rise to the most discussion at the Congress were the standardization of methods of determining speeds and other characteristics of photographic materials for commercial purposes, and the standardization of the dimensions of 16-mm. sound-film.

Sensitometry Standardization.—The question of working out a

method of determining speeds and other properties of photographic materials that will be satisfactory for international use has engaged the attention of the International Congresses over a long period of years. The problem is not simple, and it is not yet solved. At the previous Congress, in 1931, the German delegation proposed a method of measuring and describing speed that was later adopted as the DIN system.

The chief characteristics of the German proposal for speed determination consisted in the use of a step tablet in conjunction with a standard lamp and a shutter that gave an exposure of $^1/_2$ second. Development was to be in a specified MQ formula and "optimal"; *i. e.*, for the time that would give the maximum speed figure when the test-strip was measured. The speed figure was determined by noting the number of the step on the tablet that gave a step on the test-strip having a density 0.1 higher than the fog. The number of this step over ten (written, for example, 21/10) was to be taken as the speed number, and called "degrees DIN."

Objection to "optimal development" was practically unanimous among the countries other than Germany. So far as the evaluation of speed was concerned, the various methods considered in addition to the DIN proposal were (*1*) the inertia method, of which the H&D system was an example; (*2*) the threshold method, of which the Scheiner and Eder-Hecht methods are examples; (*3*) the use of the exposure required to give a certain gradient in the underexposure portion of the characteristic curve.

The American Committee favored a method in which speed was determined by the exposure required to give a certain contrast (*i. e.*, a certain gradient or slope of the characteristic curve) for certain conditions of development. It was argued that the thing that mattered was not the exposure required to give a particular density, but the exposure required to give a certain contrast in the shadows of the subject. They were, however, not prepared to make any recommendations about it at the moment, because it had not been tried out in practice to any great extent. One objection also was that it was not simple to carry out. This, however, was remedied by the description at the Congress, in a paper by L. A. Jones and M. E. Russell, of the Kodak Research Laboratories, of a simple piece of apparatus for determining speeds according to this system that was not more difficult to use than the instrument used for determining the DIN or other speeds.

(V) PUBLICATIONS AND NEW BOOKS

A rather small number of new books was published during the year and no new periodicals were known to have been issued. The bulk of the new books were devoted to amateur cinematography.

The *Cinema Digest*, omitted unintentionally from last year's report, is now in its second volume. It represents the official monthly organ of Local 666 of the I. A. T. S. E., Chicago, Ill.

Books of primary interest that have been published since the last report of the Committee (May, 1935) are as follows:

(*1*) Motion Picture Almanac (1935), *Quigley Publishing Co.*, New York.

(*2*) Year Book of Motion Pictures (1936), 17th Ed., *Film Daily*, New York.

(*3*) Kinematograph Year Book (1936), *Kinematograph Publications, Ltd.*, London.

(*4*) Yearbook of the Ciné-Amateur (Jahrbuch des Kino-Amateurs-1936) edited by W. Frerk, *Photokino Verlag.*, Berlin.

(*5*) Publications from the Scientific Laboratory, Agfa Photographic Division (Veroffentlichungen des wissenschaftlichen Zentral Laboratoriums, Agfa Photographischen Abteilung) Vol. IV, I. G. Farbenindustrie A.-G., *Hirzel*, Leipzig.

(*6*) History of the Discovery of Photography; G. Pontonniée, translation by E. Epstean, *Walker Engraving Corp.*, New York.

(*7*) Photographic Developers (Fotografische Ontwikelaars); M. C. F. Beukers, *Waltham, Jr.*, Delft.

(*8*) The Photography of Colored Objects, 13th Ed., revised, *Eastman Kodak Co.*, Rochester, N. Y.

(*9*) Practical Photography and Cinematography, Vols. I–III, edited by E. Malloy, *Newnes, Ltd.*, London.

(*10*) Bluebook of Projection; 6th Ed., F. H. Richardson, *Quigley Publishing Co.*, New York.

(*11*) Movie Making Made Easy; 2nd Ed., W. J. Shannon, *Moorfield & Shannon*, Nutley, N. J.

(*12*) The Leica Manual; W. D. Morgan and H. M. Lester, *Morgan and Lester*, New York.

(*13*) The Ciné Amateur's Workshop; D. C. Ottley, *Newnes, Ltd.*, London; also by the same author, Practical Set Structure for the Amateur Cinematographer; *Pitman and Son*, London.

(*14*) Making Better Movies; Revised Ed., A. L. Gale and R. C. Holslag, *Amateur Cinema League, Inc.*, New York.

(*15*) Film Titling; G. P. Kendall, *Newnes, Ltd.*, London.

(*16*) Ciné Photography for Amateurs, 2nd Ed.; J. H. Reyner, *Chapman* & *Hall*, London.

(*17*) Film for All (Der Film für Alles); W. Kross, *W. Knapp*, Halle.

(*18*) Film Acting; V. I. Pudovkin, translated from the Russian by I. Montagu, *Newnes, Ltd.*, London.

(*19*) Study of the Chromatic Sensitization and the Desensitization of Photographic Emulsions (Étude de la Sensibilisation chromatique et de la Desensibilisation des Emulsions photographiques); A. Chariou, *Gauthier-Villars*, Paris.

APPENDIX A

General Field of Progress of the Motion Picture Industry in Great Britain

General.—In Great Britain, the cautious optimism apparent in 1934 appears to have been amply justified by the year 1935, especially so far as the motion picture industry was concerned. The prestige of the local producers has been enhanced by the improvement in the quality of their output, and it is significant that there is now a widely approved demand in trade quarters that the restriction be removed requiring importing producers to offer a proportion of films of local origin. In the industry generally, the promise of the previous year has fructified, and upon all sides investors are busy with schemes and projects for reaping the potential harvest. Recently the interest of strictly orthodox financiers has been aroused by a thorough statistical investigation of the industry's possibilities.

Photography.—Color continues to interest the producers, and in this connection Publicity Films have found considerable scope for color in advertising films. Moreover, the formation of Technicolor, Ltd., and the proposal to erect a laboratory at Denham during 1936 have given impetus to the color movement, and it is believed that at least one major studio may produce a color picture during 1936.

With the increased demand, trick photography has received much attention locally, and the assistance of experts from other countries has been called in. Rear projection work has also been advanced, and one local studio, the Stoll, Cricklewood, claims to be able to produce results of an exceedingly high order. The system in use at this studio, developed by Desmond Dickinson, the chief cameraman, utilizes an arc taking a current of about 300 amperes. The light from

this arc is concentrated upon a specially cooled Bell & Howell camera gate by a 15-inch reflector, the gate and associated mechanism being located in a special sound-proof chamber having transparent sides. Cooling of the gate is effected by a blast of air chilled by being passed through a cooling bath of liquid air. The intense light enables the background to be projected upon a thick paper screen only four feet from the foreground, giving a brilliant, realistically positioned background without any "hot spot."

FIG. 20. Developing machine (*Andre Debrie Co.*).

Laboratories.—Several laboratories have now installed the photoelectric densitometers made by Watson & Sons, Ltd., and a total of four laboratories has now been equipped with Eastman type II*b* sensitometers. Owing to the introduction of Eastman Super *X* negative into the English studios, several laboratories have had to modify their developing machines slightly to allow for the longer development time required by this material. Most laboratories develop a normally exposed Super *X* negative to a gamma of about 0.70, as compared to 0.65 for the supersensitive material.

Studios and Laboratory Equipment.—Much interest has been aroused by the announcement of a new Debrie multiplex high-speed developing machine having a frictional film drive and working in daylight (Fig. 20). The new laboratories at Denham will be equipped with these units. The Debrie Company has also brought out a series of film reduction printers, each capable of producing two or more reduced prints at a time, the range including a continuous motion printer for producing 16-mm. sound film. This firm has also produced a machine for printing one to five standard copies simultaneously from one or two single negatives. Vinten & Co., of Cricklewood, are about to present a new 16-mm. printer capable of printing at speeds up to 70 feet of film per minute, and having a synchronous automatic printer light. These film printers include a sloping slit at the printer point that filters out flutter or slip frequencies in excess of 50 cps. Vinten is also producing a new bi-pack magazine for color-film cameras, in which the reels are mounted side by side instead of one above the other, as in leading existing types. Another purely local development, made also by Vinten & Co., is a film-matting machine, with which scratches in film base can be eliminated. Messrs. Frank Brockliss have put out some very popular arc spotlights embodying their patented "Stellmar" optical system. This system is satisfactory for use with arcs operated by direct or alternating current; the feature of utilizing light from both carbons in the latter case producing a maximum efficiency and non-fluctuating illumination.

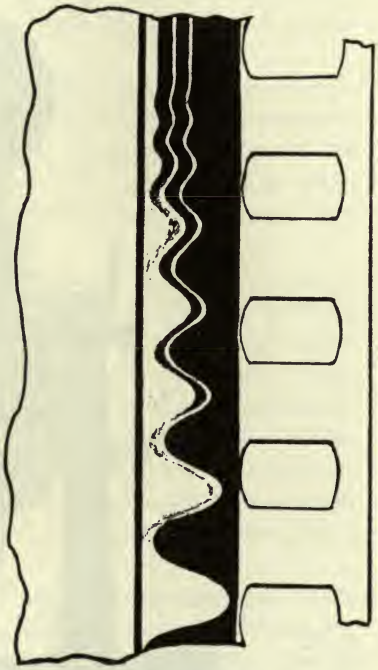

FIG. 21. Sound-track produced by Visatone noiseless recording system (*Technical & Research Processes, Ltd.*).

Sound Recording Equipment.—A feature of this field has been the development of condenser microphones by certain of the smaller

companies. A smaller microphone of this type with a compact single-stage amplifier has been evolved by Technical & Research Processes, Ltd. (Visatone), and a larger unit has been made by Midgeley & Harmer, Ltd., for the Ambiphone system. The Ambiphone unit comprises forty untensioned small diaphragms arranged on a grid-like structure, and is said to be simple to manufacture, free

FIG. 22. Double-film preview attachment for projectors (*RCA, Ltd.*).

from cavity resonance, and non-directional. The impedance of the Ambiphone unit is given as about two to five megohms, and the frequency-response range and sensitivity are claimed to be very satisfactory. New Ambiphone equipment has been installed at British International Pictures Studios at Elstree.

The Visatone Company is introducing a new system of noiseless recording using an unbiased oscillograph. The sound-track (Fig. 21)

is produced by moving the shadow of an edge of a shutter or mask to and fro about the center line of the sound-track by movement of the oscillograph mirror in the well known way; and, in order to reduce background noise, a toothed mask having teeth of unequal length and shaded off in density at their ends is interposed in the light-beam between the first-mentioned mask and the mirror. The mask is moved out of the light-beam as the sound volume increases, so that a gradually increased area of the sound-track is cleared and becomes available for modulation.

The RCA Company has developed locally a new preview attachment for projectors (Fig. 22). The attachment is built in the form of a clover leaf and replaces the lower Simplex magazine with very little modification. The same firm has also evolved an immediate playback disk recording equipment using cellulose acetate coated aluminum disks.

Cinemas and Camera Equipment.—On the theater side of the industry, the generally healthy tone of the industry has been reflected accurately. Theater building continues at an increased tempo, about 120 new houses having been opened during the year. A test case for the prevention of the exhibition of non-flam substandard film in ordinary public halls was lost, and in the industrial districts exhibitors are complaining of free shows now being given in taverns. Statistics show that these performances draw a considerable number of patrons to the houses concerned and enormously increase liquor consumption.

Industrial and Educational.—The Gaumont Company has been very active in the educational field and has formed a special company (Gaumont-British Instructional, Ltd.) which has built new studios devoted entirely to the production of instructional films. An extensive library of such films has already been prepared. The Gaumont Company has also produced a new 16-mm. talking picture equipment, of which there are four models, for use in schools and in the home.

The Western Electric Company reports that more than 8000 sponsored shows have been given through their road show service during the year. On the industrial side, business has been well maintained. The high-speed camera exploited by this Company in conjunction with Messrs. Kodak, Ltd., also continues to demonstrate its utility in the study of rapid mechanical movement.

Amateur Field.—Probably one of the most important factors affecting the amateur field has been what appears to be the set-back in the

development of television. This was heralded in 1934 as being nearly ready to be publicized upon much the same scale as early radio, and high hopes were entertained. However, during the year it became increasingly apparent that the expectations of the Selsdon Committee were not likely to be realized. Moreover, the attention of the library-forming companies to the rapid printing of newsreel films on sub-standard stock has also contributed to the topical value of home outfits. Films of such events as the wedding of H. R. H. Duke of Kent and of the Jubilee were available to borrowers while public interest was still at its height.

Amateur film companies continue to flourish and expand, and there are now probably about 200 throughout the country. In this connection, the Marguerite Sound Studios, which are well known in the motion picture industry, are preparing a program to enable film societies to supplement their present film activities which are chiefly silent, so that they can produce and exhibit talking pictures without any more elaborate sound equipment than an electric gramophone.

Broadcasting.—The linkages between the broadcasting industry and the motion picture industry have developed and strengthened during the year. The British Broadcasting Corporation continued to use film subjects for broadcasting purpose, the broadcast version of the film *Friday the Thirteenth* being a notable example. Also, film recording for playback broadcasting is said to be becoming increasingly important; and Publicity Films, who have exploited that field, are planning to erect a new studio especially to handle the business obtained. On the technical side, the research work conducted by engineers of the British Broadcasting Corporation relating to studio construction is of interest, a valuable contribution to the available information on acoustics having been made in a paper recently presented by H. K. Kirke and A. B. Howe to the Institution of Electrical Engineers in London. Valuable information is also being collected as to the capabilities of various direct-recording systems. For example, the Stille-Marconi system of magnetic sound recording and the Marguerite system of disk recording are being used for immediate playback recording in England, and it is reported that the Nublat system of recording by cutting through a film strip to obtain two oppositely phased records, is proving quite promising.

In conclusion, it may be said that as a whole the British Industry has experienced a successful year and appears to be upon the threshold of a period of still greater prosperity.

APPENDIX B

General Field of Progress of the Motion Picture Industry in Japan

During 1935 the production of motion pictures in Japan was quite active. The total footage and the number of pictures produced show an increase over 1934. Theater attendance increased in proportion, and new and better theaters were opened in the leading cities. Along with the introduction of better theaters, the status of motion pictures as entertainment has been gradually raised. The result has been a demand for better pictures. The leading studios have attempted to meet this demand, and in so doing have limited their production of features to the point at which they have found it necessary to buy more imported pictures and more productions from independent producers. The general trend in Japanese pictures has continued toward the so-called modern style, as opposed to the ancient style or costume play, although some of the best pictures of the year were of the classical type.

Studios.—With the advance of sound, production in Tokyo has increased to a great extent. Nikkatsu have built a large new studio in the suburbs of Tokyo, and Shochiku have moved from their quarters in Kamata farther out where they have more space and, incidentally, new quarters. P.C.L., a rather recent entrant into the motion picture field, put through plans for expanding their studio in the suburbs of Tokyo.

The stages in Kyoto that were destroyed in the typhoon of 1934 were replaced in 1935, and in most cases this meant the replacement of silent stages by sound stages.

Studio Production.—As mentioned previously, the total footage produced increased over that of 1934. Among the features 60 per cent were with sound. Although there was a much greater footage of silent pictures (counting shorts and quickies) produced than sound, due to the comparatively small distribution of silent pictures, at least 60 per cent of the pictures being shown at any one time were sound pictures.

Sound Equipment.—Nikkatsu have increased the number of Western Electric channels to three, and have been renting a fourth from another licensee. Shochiku have been continually increasing the amount of their own sound equipment, devised by Mr. Tsuchihashi. There is also one RCA channel in use at the Uzumasa Studio in Kyoto, and other smaller independent studios have either acquired or added to their sound equipment. Except for the Western Electric

and RCA equipment, the sound equipment in use has in the past employed flashing lamps, but during the past year several have changed to variable-width recording. It is reported that some light-valve equipment other than Western Electric is in use, but due to the secrecy that surrounds this equipment, it is not possible to state so definitely.

Laboratory Equipment.—There has been a considerable increase in the number of continuous machines in service both in the laboratories and the studios. J. O. Studios and Far East Laboratories, Ltd., have built new laboratories in the Tokyo district equipped with modern laboratory machinery. P. C. L. Studio has installed a continuous machine, and Shochiku is equipping the laboratory in their new Ofuna Studio with continuous machines. Other machines were either under consideration or in process of being installed at the end of the year.

Technical Advancement.—There has been a gradual increase in the use of sensitometric control in the laboratories, resulting on the whole in an improvement in quality. Sound quality in general has improved, following a course in this respect similar to that of sound in the United States. Development has been delayed due to a lack of equipment and money. Because of the relatively small distribution of pictures made in Japan, the returns per picture are correspondingly small, which means that there is little money available for investment in equipment.

Distribution.—The average number of prints per picture is about seven, which gives an indication of the limited distribution. Total theater attendance was in the neighborhood of 240,000,000, at an average admission fee of 20 sen. When this is compared with the turnover in the United States for about the same number of pictures, it is easy to understand why it is necessary to economize in film and equipment.

Distribution branches have been established in Manchoukuo. Although to date these have not been a very great source of revenue, this market offers an opportunity for expansion of the very small export market for Japanese pictures.

Theaters.—There has been a steady rise in the number of motion picture theaters during the past ten years, until now there are well over 1500. Of these, more than 900 are wired for sound. During 1935 there was quite an increase in the number of sound installations, and many theaters replaced their existing equipments with better ones.

In Japan it has always been the custom to have present a commentator who explains the picture to the audience and, with silent pictures, often supplied some of the dialog, many of them being very clever at doing so. Every year, as talkies advance, their services become less and less necessary, and the disposition of these men is a problem that regularly confronts the big theater chains. Although there has been a gradual decrease in the number of these commentators, there are still some 6000 persons listed at this occupation.

Imported Pictures.—There appears to be an increase in popularity of imported pictures, particularly in the cities. This has been due partly to a lack of first-class locally produced pictures. European pictures increased in proportion to the American product, 20 per cent of the imported pictures being European. This is the highest point they have reached during the past five years.

Superimposed titles have come into general use as a means of explaining the picture to those who can not understand all the dialog. Several pictures were scored with Japanese dialog this past year, and caused much comment among the critics and the trade journals. It seems that many of those who go to see foreign pictures prefer them in the original tongue, while others enjoy being able to understand the speakers, which they can not do in the original. The argument has not been settled, but it is not likely that there will be much scoring done so long as imported pictures remain so popular in their original tongue.

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A STUDY OF THEATER LOUD SPEAKERS AND THE RESULTANT DEVELOPMENT OF THE SHEARER TWO-WAY HORN SYSTEM*

JOHN K. HILLIARD**

Summary.—*A description of recent work carried on to study and formulate requirements to be met by the sound systems of motion picture theaters in order that the reproduction may be of a quality consistent with the recording technic available for some years to come. After setting up requirements relating to sound equipment; load capacitites; efficiency; volume ranges; transient, phase, and attenuation distortion; horn distribution characteristics; size; weight; costs; etc., the paper goes on to describe the design, installation, and performance, of the Shearer two-way horn system, engineered to meet the high standard of performance set up. The material of the paper is useful not only in connection with motion picture sound systems but also with public address systems and home radio equipments.*

INTRODUCTION

The present investigation was undertaken with a twofold purpose in mind: first, to study thoroughly the more important types of extended-range loud speaker systems in current use, and second, to develop, if possible, a system which would combine practicability for theater use with as great an improvement in quality and efficiency as could be attained without greatly increased cost. The first objective necessarily involved an effort to learn as much as possible of the "why" as well as the "how" of the systems and individual speakers studied, while the second led to considerable investigation of certain aspects of loud speaker design, some of which—at least in the literature of the subject—seem not to have been sufficiently emphasized in the past.

Any investigation of as wide scope as the present one would inevitably furnish many facts not pertinent to the main issue, but useful in other fields. The main body of the paper, however, has been written

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* Reprinted from the *Technical Bulletin* of the Research Council of the Academy of Motion Picture Arts & Sciences, Hollywood, Calif. (March 2, 1936).

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with the problem of the reproduction of sound for motion pictures ever in mind, and should be read from that viewpoint. It is felt, however, that the results referred to may form a definite contribution to other fields, such as public address work and home radio.

SOUND REPRODUCTION SYSTEMS FOR MOTION PICTURE THEATERS

The art of reproducing sound in motion picture theaters is now about eight years old. During this time there has, of course, been considerable improvement, but there has been only one major change in the standard theater installation. This change was the adoption of the wide-range[1] and high-fidelity systems after 1933. The principal modifications involved were: first, a partial fulfillment of greatly needed increase in amplifier carrying-capacity; second, the adoption of speaker systems which provided for the division of power between two or more groups of speakers, each operating over a limited frequency range; third, improvements in the sound-head which reduced flutter. While these improvements considerably raised the standard of reproduction in the theater, it was felt that the loud speaker system still constituted the principal limitation to naturalness of reproduction. An investigation was accordingly made to determine whether a speaker system could be developed which would economically replace the present systems while providing the much-needed increase in fidelity. This was found to be the case, and it is the purpose of the present paper to describe this system and the results obtained with it, and to compare it with previous systems.

Since it was not known how great a departure from a full-range linear response could be tolerated for the purpose in hand, it was considered advisable to start with a system as near this as so far achieved, even though the form of apparatus available would by its size and cost prohibit its use for theater installations. From this it was determinable how much deviation was allowable and necessary in order to obtain a commercially practical system. Such a linear system was made available,[2] and a series of tests led to the following specifications, which were found to be adequate for theater reproduction, taking into consideration further developments in recording which may be expected within the next few years.

SPECIFICATIONS

Flat Over-All Frequency Characteristic.—The system shall not deviate by more than ±2 db., from 50 to 8000 cycles over the entire angle of distribution within ten feet of the mouth of the horn.

High Electroäcoustical Efficiency.—This shall approach 50 per cent in order that the required amplifier capacity need not be too great.

Volume Range.—The volume range shall be at least 50 db., and preferably 60 db.

Cost.—This should be reasonable.

Absence of Transient Distortion and "Fuzziness."—The electroäcoustical transducer shall be of such construction that it shall not generate objectionable harmonics up to the peak power required, and the phase delay between units shall be such that the sound will be equivalent to that coming from a single source.

Suitable Angular Distribution Characteristics.—The sound shall be radiated through a horizontal angle as great as 110 degrees and a vertical angle of 60 degrees, with nearly uniform response at all positions.

Reasonable Compactness and Portability.—Low weight.

Amplifier Capacity.—The installed amplifier capacity shall be such that one acoustic watt per 1000 square feet of floor area can be delivered when the auditorium is adjusted for optimum reverberation time.

A system which will conform to or exceed these specifications has now been developed, and can be constructed at moderate expense.

In order to take advantage of these characteristics it has been found that when film is reproduced over a system such as this, it is necessary to keep the flutter from the sound-head no greater than 0.1 per cent. Although the problem of flutter has been satisfactorily solved, and heads are commercially available which will pass the 0.1 per cent flutter specification, it should be pointed out that by far the largest majority of heads in use today will not meet this specification.

POWER AND FREQUENCY REQUIREMENTS

The history of the electrical reproduction of sound has been one of continual increase in amplifier carrying-capacity, and in this respect the theater installation is no exception.[3] Originally, output powers from 2.5 to 12 watts were considered adequate for most houses. With the advent of the later systems now in use, these powers were recommended to be increased from 3 to 6 db. depending upon the size of the house. It has been found from this investigation that it is both practical and eminently desirable to make a further increase of at least the same amount. The figure given of one acoustic watt per 1000 square feet of floor area is felt to be the minimum which will do justice to the advanced conception of reproduction with modern recording technic. It is of interest to note that this figure can be achieved allowing for considerable latitude above this point without danger of mechanical damage to the units.

The advisability of extending the frequency-range of a reproducing

system must be determined by balancing the gain in naturalness, obtained by the extension, against the resulting increase in noise and extraneous sounds. In the present state of the recording art, a characteristic flat to 6000 cycles is the least that will do justice to the film; an extension to 7000 or even 8000 cycles is advisable, and a further extension is not. This is so because a further extension becomes of less and less value, due to the decreasing sensitivity of the ear and the small amount of energy in this region, and especially because above 8000 cycles, noise, flutter, and harmonics due to recording deficiencies become decidedly the limiting factors. Incidentally, since practically all recording systems include a low-pass filter with a cut-off in the neighborhood of 8000 cycles, there is nothing on the film at high frequencies to be reproduced.

Once the high-frequency limit is chosen, the low-frequency limit is automatically fixed. It has been found that for ideal balance the product of the two cut-off frequencies must be fairly close to 400,000, so that for an 8000-cycle upper cut-off, the lower becomes 50 cycles.

HIGH-FREQUENCY HORN

One of the principal limitations of present theater installations is the bad directional characteristic. The plain exponential horn has a directivity which varies with frequency; low-frequency sound is projected fairly uniformly over a wide angle, but as the frequency is increased this angle decreases rapidly until at frequencies of several thousand cycles practically all the energy is emitted in a narrow beam. The result of this is that the reproduction becomes very "drummy" or "bassy" for that portion of the audience whose seats lie well off the axis, while the opposite is true for seats located directly on the axis. In the present system this effect is eliminated by using a radiating system for the high-frequency unit which is composed of a cluster of small exponential horns, each having a mouth opening of approximately 60 square-inches. These individual units are stacked in layers to form a large horn, the mouth-opening of which is spherical in shape. The principle of this high-frequency unit can best be illustrated as a further compacting of the typical cluster of loud speakers, as customarily used in auditoriums and stadiums for public address systems and announcing, except that the whole array is fed from a common header and driven by two dynamic units. This type of high-frequency radiation is also a feature of the aforementioned reference system.[2] However, the reference horn,

having been developed to a very limited angle and being driven by a single mechanism, was not adaptable to theater use as more than one horn became necessary for full coverage. This would result in non-uniform distribution as well as complete loss of coverage for a large part of the auditorium, should one unit fail during a performance.

One of the features of the reference system is the use of a single diaphragm to reduce phase distortion. Inasmuch as theaters require parallel operation as protection in the case of failure of one unit, experiments were made with a *Y*-throat and two units. As a result

FIG. 1. The *Y*-throat.

of these experiments, it is now recognized by all concerned that any increase in phase distortion which may be introduced by the *Y*-throat is negligible.

The diaphragms are made of duralumin 0.002 inch thick and have an area of 6 square-inches. The diaphragm is mounted on the back of the assembly, and by the use of an annular opening,[2] the sound that is admitted to the throat within the unit has minimum phase distortion (Fig. 2). This is still further reduced by making this throat exponential, beginning at the annular opening, and avoiding the sharp discontinuity that may exist with a tubular throat. Two units are connected by means of a *Y*-throat to the multi-channel horn

which tends to reduce the distortion of high throat-pressure. The field excitation requires 25 watts per unit.

The directional characteristics of the resulting unit are very satisfactory as found in theater installations. It should, perhaps, be emphasized that lack of good distribution can not be corrected by equalization in the electrical circuits, since for any given adjustment, the over-all response is a highly varying function of position in the house. Although the characteristic can be made flat for any given position, it

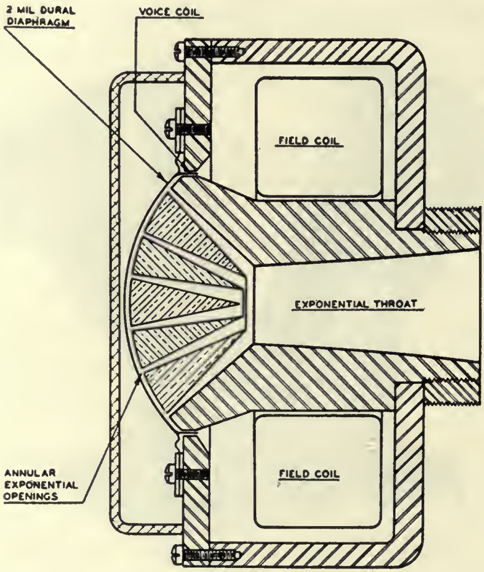

FIG. 2. Lansing No. 284*E* high-frequency unit.

can not be made so for all or even a large part of the house by this method.

LOW-FREQUENCY HORN

In the case of a low-frequency unit, a suitable driving mechanism was not available, and it became necessary to develop one. The unit finally adopted consisted essentially of an exponential horn with a mouth area of 50 square-feet, and an axial length of 40 inches, driven by four 15-inch dynamic units of special design. The mouth opening was extended laterally to form a flat baffle 10 × 12 feet. The paper cones are dipped with lacquer to prevent them from absorbing moisture, which would vary their response. They are connected in series-

parallel to give a desirable impedance characteristic as well as providing insurance against complete failure of the system in the event that any individual unit should fail. The angle of distribution is uniform through an arc of 50 degrees on each side of the axis. The use of a horn instead of a flat baffle-board for low frequencies has several advantages. The efficiency is raised from 10 or 15 per cent to better than 50 per cent, which effects an enormous reduction in amplifier capacity. Undesirable radiation from the rear of the unit is considerably reduced and, as a result, the usual objectionable backstage low-frequency "hang-over" is decreased to a negligible amount.[1] For further compactness and rigidity, the low-frequency horn may advantageously be folded, and in this form retains the same charac-

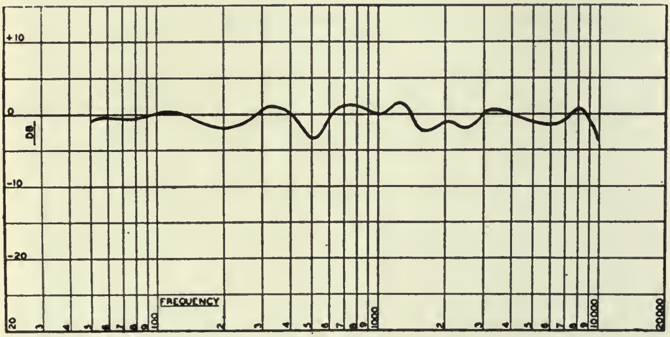

FIG. 3. Output characteristic; Shearer horn system. Measured on normal axis, 10 inches from horn.

teristic if the air-path length be maintained unchanged. This modification was contributed by H. F. Olson of RCA Manufacturing Co. The loading provided by the air column of the horn decreases the excursion of the diaphragms as compared to the excursion necessary to produce equivalent output from a flat baffle array, and distortion is correspondingly reduced (Fig. 3).

With the low-frequency horn length as specified in the design under discussion maintained approximately equivalent to the length of the high-frequency horn, there is no time delay between the component sounds from the two horns.

HORN ASSEMBLY

The folded horn is assembled in sections, each section containing two driving mechanisms. They may be stacked one upon the other,

depending upon the number required. Each section is adequate for an output from the amplifier of 25–30 watts for the required minimum harmonic content. If it is desired to secure a wide lateral distribution the sections may be placed side by side. Section *AA*, Fig. 4, shows the construction of the horn.

The entire horn is assembled so that the center of the high-frequency unit is approximately 50 to 60 per cent of screen height. This position has been found by years of use to be the center of activity or "presence" on the screen, and since the high frequencies are responsible for determining the "presence," the unit was so arranged. In

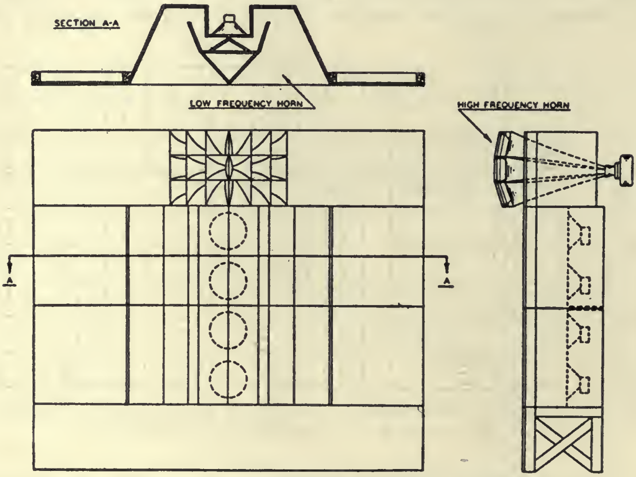

FIG. 4. Shearer two-way horn system; folded type.

order to restrict the sound as nearly to a point-source as possible, the low-frequency horn is maintained at a position near the high-frequency horn (Fig. 5).

The complete assembly is a unit so that it can be moved away from the screen or raised and lowered with the screen with minimum effort. The use of sections for the low-frequency horn allows the horn to be shipped and moved into spaces which have standard size doors.

DIRECTIVITY

For both the low- and the high-frequency units a certain amount of directivity is desirable. For most houses there should be but little energy radiated at angles greater than about 45 degrees from the

axis, since such energy will be reflected from the walls and since for the best illusion the ratio of direct to reflected sound should be as high as possible.

There is one additional consideration with regard to directivity which should be mentioned. Dr. V. O. Knudsen[4] has shown that at the higher frequencies, *e. g.*, at 10,000 cycles, absorption of the at-

FIG. 5. The folded-horn assembly.

mosphere may become very serious, being as great as 0.2 db. per foot under certain conditions of humidity and temperature. In large and deep houses this would result in a serious loss of high frequencies in the rear seats. This effect can be considerably reduced by increasing the high-frequency radiation from those horns of the unit which serve these seats. It may be done by putting a suitable amount of absorbing material in the other horns and re-equalizing to bring the over-all response up to standard for the front seats. These artifices will probably not be required in most houses.

HARMONIC CONSIDERATIONS

One major defect of commercial loud speakers is their large amplitude distortion. One of the striking improvements in the new system is its "cleanness" of reproduction at low frequencies. The measured harmonic content is less than 4 per cent at 40 cycles, for 30 watts' output. This is due in large part to the use of a thick and comparatively soft cone which can be driven to full excursion without break-up and consequent harmonic production. It was found by actual listening tests that with a pure tone of 40 cycles impressed,

FIG. 6. Single-section, low-frequency folded horn with 52-degree high-frequency units, for use in studio viewing rooms and small theaters.

most of the cone speakers investigated gave a greater apparent loudness than the speaker finally adopted. However, when a direct comparison was made by keying the amplifier from the new unit to the unit under test, it was at once obvious that the output of the new one was fairly pure 40-cycle tone, while that of the other speakers consisted of, in most cases entirely, the second and higher harmonics. Direct measurement of the acoustic output showed that, in spite of its low apparent loudness, the fairly pure output of 40 cycles was actually about 6 db. higher than that of the other speakers.

This great increase in apparent loudness due to transferring part of the fundamental power into harmonics in the conventional speaker

is very striking, and is undoubtedly the explanation for the alleged high efficiency of many present-day speakers of all types. The loudness of the harmonics is not due to the rapid change in the sensitivity of the ear at low frequencies, which would favor the harmonics at the expense of the fundamental, since it occurs also at fairly high frequencies where the sensitivity of the ear is varying in the opposite way with frequency. With one particular pair of units tested, the effect was more striking at 1000 to 2000 cycles than at any other frequency. It is equally great with complex sounds, such as speech and music, although here the change in quality is somewhat less with

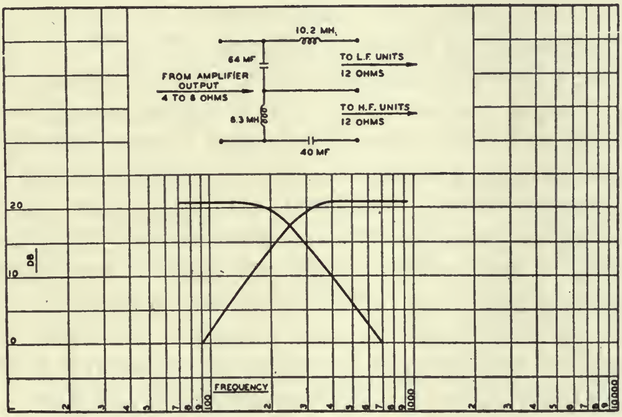

FIG. 7. Series type dividing network; Shearer horn system.

respect to the change in apparent loudness than in the case with pure tone.

PHASING

Another important advantage of the new system is that it can easily be made to fulfill the requirements that the virtual sources of all the components of the reproduced sound shall coincide in the vertical plane. This condition is impossible to attain with divided-frequency-range systems now in use, in which the axial lengths of the several types of horns in a given system are widely different. In this respect, a two-unit system is much easier of adjustment than a three-way system.[1] It might be thought that since the time-delay is so small, of the order of a few milli-seconds, the effect would be inappreciable. This is true for certain types of sound, such as sustained

musical passages, but with dialog and especially certain types of sound effects which are of the nature of short pulses, a very objectionable distortion is usually noticeable. A striking demonstration of this fact was obtained by recording a tap dance. When this was reproduced it was found that the system with a very small time-delay afforded naturalness of reproduction, but that systems which had an appreciable delay reproduced the scene with far less realism. In fact, the sound did not appear to come from the screen, and, in addition, the tap was fuzzy in character, with a decided echo.

This effect sounds somewhat like that of transient distortion due to the use of a filter with too sharp a cut-off, but it is actually more analogous to the echo effect often observed on long lines and with certain types of phase distortion networks.

A recent paper[1] discusses the features of the three-way system including some of the limitations which require special installation technic for the setting of horns, backstage draping, phasing of various horn positions, position of horns for distribution, and setting of volume between horns. Familiarity with these data will assist in appreciating the principles of the present system.

It should be pointed out that the over-all frequency response curve of the system should not fall off too rapidly beyond the cut-off frequencies, or objectionable transient distortion will result. Probably the maximum slope that can be tolerated is of the order of 20 db. per octave, or roughly, that of a single-section constant-k filter.

DIVIDING NETWORK

The frequency chosen for the critical frequency of the dividing network is governed by several factors. If this frequency is too low, it leads to uneconomically large values of capacity in the network, and to impracticably large horns for the high-frequency unit. If too high, there is danger of running into the characteristic dip which seems always to be present in large cones; and, also, it would result in dividing the prime energy of speech sounds between the two units, which is objectionable from the standpoint of good "presence." If the critical frequency is chosen as approximately 250 cycles, a good compromise results (Fig. 7).

A dividing network was chosen which gave fairly rapid attenuation, 12 db. per octave, in order to keep any appreciable low-frequency energy out of the high-frequency unit, and to minimize the effect of irregularities encountered in the response curve above the designed

range of the low-frequency cones. This lies somewhat above 400 cycles for an efficient low-frequency unit. Certain dividing networks in current use have attenuation curves of such gradual slope that at some frequencies the irregularities in response of the speakers are actually greater than the attenuations of the network.

The network is designed so that the reflected impedance of the horn on the amplifier is approximately 2.5 times the amplifier impedance. The loss in the network is less than 1 db., in order that the full capacity of the amplifier may be utilized.

MEASUREMENTS

While it is recognized that indoor response measurements do not have the degree of precision that may be had in free space, they

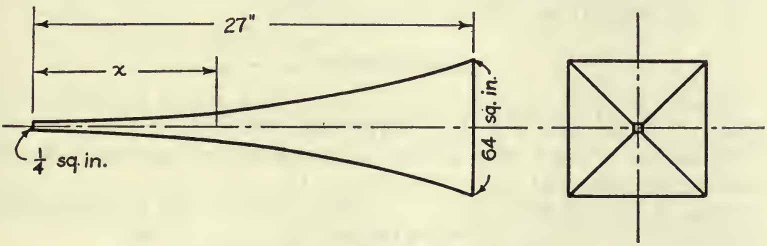

FIG. 8. A typical individual channel.

nevertheless do represent conditions under which the loud speakers must actually be used for motion pictures. Also, for the purpose at hand, comparative measurements are sufficient, and were verified by listening tests which, in the end, is the final criterion (Fig. 3 shows average response).

Irregularities in the sound-pressure at the microphone due to standing-wave patterns in the room are minimized by the use of a conventional warble frequency, varying ±25 cycles at a 10-cycle rate. Tests have been run which indicate that the warble is effective only below 2000 cycles. Above this point, the standing waves do not interfere with the correct interpretation of the response curve.

The measurements were taken in a stage 100 × 70 × 35 feet, having a reverberation time of one second at 512 cycles per second. By making the measurements indoors, tests could be made rapidly on a large number of units without the interference from outside noises, due to a 60-db. insulation between the inside and the outside provided

by the building. The response curves were measured using a high-speed level indicator[5] capable of responding to a change in level as rapid as 300 db. per second.

Douglas Shearer, head of the Metro-Goldwyn-Mayer Sound Department, brought about and directed this project. This development was engineered by the writer and contributed by Metro-Goldwyn-Mayer Studios. The coöperation of the following companies is gratefully acknowledged: Electrical Research Products, Inc.; RCA Manufacturing Co.; Lansing Manufacturing Co.; and Loew's, Inc. These companies assisted by making available test equipment, the reference system, and staff and theaters, which greatly facilitated the work and produced a coördinated result not otherwise possible. The writer wishes to acknowledge also the contribution of the Metro-Goldwyn-Mayer Sound Department, and, in particular, R. L. Stevens, who carried out the mechanical design.

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APPENDIX

Low-Frequency Exponential Horn

Fundamentally, the design of a low-frequency exponential horn follows the same treatment as that accorded a horn for high-frequency response. There is, however, a greater tolerance allowable in deviating from theoretically calculated values: namely, expansion rate (governing value of cut-off frequency), mouth size, and nature of cross-section. Discontinuities which would be out of the question in high-frequency design may be permitted with little loss in a low-frequency horn. Numerous tests have borne out the above statement. A horn of folded cross-section has been chosen for general use in this system, because it permitted a compactness of design not possible with a straight exponential horn. Sufficient loading has been obtained in a small space to permit the cone-driving units to operate at their optimum efficiency.

For the purposes of illustrating the method of computation, a brief summary of

the calculations involved in the design of a straight exponential horn will be given:

The cut-off frequency was chosen as 50 cycles per second. A 50-cycle wave has a length of 271 inches. The distance across the mouth of the horn should be equal to at least one-quarter of the wavelength of the lowest frequency it is desired to transmit. This value for the horn in question gives a minimum mouth size of 68 inches. The size of throat must be sufficient to accommodate four 15-inch cone speaker units. A throat size of 30 $\times$ 30 inches was chosen.

It has been found that an exponential horn whose area doubles every 12 inches will have a cut-off frequency of 64 cycles per second; one whose area doubles every 6 inches, a cut-off frequency of 128 cycles per second. From the above relationship the length for the area of the present horn to double may be found by the simple proportion $64/X = 50/12$, from which $X = 15.36$ inches. From the general horn equation:

$$A_x = A_o \epsilon^{Mx}$$

where: A_x = Area at any point X
A_o = Area of throat (chosen above as 900 square-inches)
ϵ = 2.7183
M = Flare constant of horn
X = Distance along horn axis from throat

M can be computed by substituting known values in the above equation:

$$1800 = 900 \times 2.7183^{M15.36}$$

from which $M = 0.045$. Then the equation for the present horn becomes:

$$A = 900\epsilon^{0.045x}$$

from which the sectional area at all points X may be computed.

For a minimum distance across the mouth of the horn of 68 inches or a minimum mouth area of 4624 square-inches, the length is determined:

$$A = 900\epsilon^{0.045x}$$

$$4624 = 900 \times 2.7183^{0.045x}$$

where $X = 36^1/_4$ inches.

It has been found, however, that while the sizes given above are satisfactory from a theoretical standpoint, an increase in loading will result in a higher efficiency. An increase in length to 44 inches with a corresponding mouth size of 80 inches, or 6400 square-inches has, as a result of tests, proved to be perhaps the most desirable size. The over-all length, inclusive of units, then becomes approximately 55 inches. This length is considerably more than is desirable for the majority of installations.

The above analysis applies to the straight type of horn rather than the folded type.

Fig. 4 illustrates a horn of folded cross-section. Here it is possible to retain optimum loading conditions in a minimum of space. It is, however, in this case mechanically impracticable to construct a horn of true exponential shape.

The mouth, throat size, and flare constant are determined as in the case of the straight exponential horn. Intermediate cross-sectional areas are approximated to those of a true exponential horn as closely as is feasible without involving constructional difficulties.

It has been found that the difference in response is sufficiently slight to justify this deviation from the theoretical.

High-Frequency Exponential Horn

The specifications require that the over-all depth or length of both low- and high-frequency assemblies shall not exceed 44 inches.

This limitation of length brought about the selection of a theoretical cut-off frequency of 220 cycles per second. This value of cut-off allowed the design of a horn which fulfilled the desired requirements, such as a spread of either 90 or 105 degrees with a maximum of six separate channels and a sufficient mouth size to present a reasonably small amount of discontinuity.

By simple proportion, as before, the length for the area of the present horn to double may be found: $64/X = 220/12$, from which $X = 3.5$ inches.

From the general horn equation, choosing $1/4$ square-inch for A_0, M can be computed by substituting the known values:

$$1/2 = 1/4 \times 2.7183^{3.5xM}$$

from which

$$M = 0.2$$

Then the equation for the present horn becomes:

$$A = 1/4 \epsilon^{0.2x}$$

from which the sectional area of the horn at all points X may be computed.

DIVIDING NETWORKS FOR LOUD SPEAKER SYSTEMS*

J. K. HILLIARD AND H. R. KIMBALL**

Summary.—*A description of the theoretical and practical design of dividing networks for use in coupling power amplifiers to loud speaker systems in which two sets of horns are used for reproducing the sound energy. Performance curves and design data are given to facilitate the engineering of such networks.*

INTRODUCTION

In the design of linear sound reproducing equipment wherewith it is desired to reproduce faithfully tones from about 50 cycles per second to about 8000 cycles per second, it is common practice to divide the frequency range into two or more parts, and to provide one or more loud speakers for each of these frequency ranges. The speakers employed for the different bands are, of course, differently designed, each speaker being particularly suitable for its own band. Since it is not possible to design speakers which will faithfully and efficiently reproduce frequencies in one pre-assigned band and sharply attenuate frequencies outside the band, it is necessary to supply an electrical network between the final power amplifiers and the speakers to deliver the correct frequency band to each of the sets of loud speakers. These networks have acquired the name of "dividing networks."

It is the purpose of this paper to discuss the theoretical and practical design of such networks and to give data from which the electrical constants may be easily selected. Only two-way speaker systems, that is, systems dividing the frequency band into two parts, are discussed. The theoretical information given, however, is fundamental in nature and may easily be extended to cover three-way speaker systems.

For the two-way system the speakers handling the lower frequencies are termed the low-frequency speakers or low-range speakers. In

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* Reprinted from the *Technical Bulletin* of the Research Council of the Academy of Motion Picture Arts & Sciences, Hollywood, Calif. (March 3, 1936).

** Sound Department, Metro-Goldwyn-Mayer Studios, Culver City, Calif.

like manner, the speakers having the job of reproducing the higher frequencies are called the upper-frequency speakers or upper-range speakers. For each of the two frequency bands one speaker unit or a number of speakers arranged in series-parallel combinations may be used, depending upon the impedance of the speakers.

Dividing networks are not usually of the sharp cut-off type, that is, they are not arranged to transmit uniformly frequencies of a given band and sharply attenuate all other frequencies. Rather, they transmit the band frequencies almost uniformly, and gradually slope off, thereby allowing a certain amount of over-lap between the assigned frequency ranges. While theoretically it may seem desirable to arrange dividing networks to cut off sharply, from a commercial standpoint the sharpness of cut-off is necessarily a compromise between expense and effectiveness. For well designed speaker systems, the rate of change of attenuation should at least be sufficient to suppress objectionable irregularities in the response of one horn in its transmitting range because of sound coming from the other horn in its suppression range. From an analysis of a large number of speaker systems it appears that the dividing network should provide at least 10 or 12 db. of attenuation one octave away from its cut-off. Concerning the maximum rate of change of attenuation which should be used, increased attenuation is accompanied by increased losses in the transmitting ranges which, for high-powered systems, at least, is to be avoided. Costs also may mount up unreasonably if a large amount of filtering is employed. For these reasons and considering the magnitude of the irregularities which one speaker produces in the transmitting range of the other, it appears that few dividing networks should employ more attenuation than about 18 db. per octave.

In a two-way system the frequency at which both sets of speakers receive equal amounts of energy is called the "cross-over point." In other words, the cross-over point is the point of separation between the two bands of frequencies. In developing speaker systems a trial cross-over point is usually arbitrarily selected, keeping in mind the characteristics of the upper- and lower-range speakers which are to be used, costs, and other items, and later moved one way or the other if found unsatisfactory when the system is operated as a whole. Where it is desirable to use a baffle board in connection with dynamic speakers for low-frequency range and a horn for the upper-frequency range, experience has shown that the cross-over point should be

placed near the lowest frequency the horn will safely transmit in its linear range, in order that the effect of time-lag between the low- and high-frequency speakers will be reduced over a large portion of the range. It is not economical to use too low a frequency, since large values of capacity are required in the dividing network and the high-frequency horn must be large to keep its cut-off low. In general, the division of the band for this reason should not be below about 200 cycles. If the band division is at higher frequencies, such as 1000–3000 cycles per second, an irregular response due to dips in large low-frequency commercial cones is likely to occur. Also, if a small baffle-board is used, there is the one inherent dip due to interference between the radiations from the front and the rear sides. From this it appears best to divide at some low frequency, 200–350 cycles, as most commercial cone speakers are reasonably flat up to this point and an excessively large high-frequency horn will not be required to transmit down to 200 cycles.

GENERAL DESIGN THEORY

A two-way dividing network consists of a low-pass filter and a high-pass filter designed to operate from a common source at their input ends. Two types[1,2,3] of such networks are in general use: namely, the shunt type, in which the input terminals of the two filters are in parallel; and the series type, in which the filters are connected in series at their input terminals. Different design methods are used for the two types, but as discussed later the types are inverse to each other. In arranging a low-pass and high-pass filter for series or parallel operation it is necessary to employ special design methods only in connection with the first half-filter sections of each of the filters, the remaining sections of the filters being designed in accordance with conventional filter practice.[2] For the first half-filter sections M-derived types are used, the filters having mid-shunt terminations for parallel operation and mid-series terminations for series operation.

Fig. 1 shows a low-pass filter and a high-pass filter, each of which has its first half-filter section shown in detail and the remaining filter sections in block schematic form. It is recognized that half-sections shown are each mid-shunt terminated M-derived types, the constant M determining the place in the frequency range where infinite attenuation is theoretically attained and also controlling the frequency configuration of the mid-shunt image impedances as shown in various books describing filter design methods.[3] Without going into the mat-

ter here it may be mentioned that a value of M equal to about 0.6 gives image impedances over the passing bands that are sufficiently close to constant resistances for dividing network purposes. The filters shown in Fig. 1, when used individually and when the filter sections contained in the block schematics are designed according

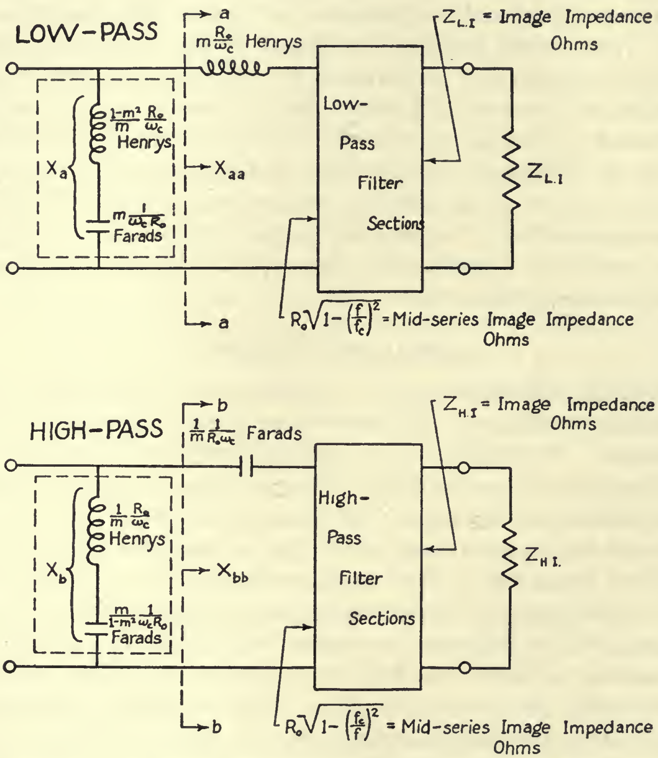


FIG. 1. (*Upper*) low-pass filter; (*lower*) high-pass filter.

to conventional filter practice, should have reasonably good attenuation characteristics.

In showing the changes that it is necessary to make in the terminating sections of the filters of Fig. 1 to make parallel operation possible, it is interesting first to consider some of the reactive impedances of the filters at different points. In order to be specific, it is assumed that each of the filters is designed for a cut-off frequency of f_c cycles per second, and that the low-pass filter has an image impedance of R_o

resistive ohms at zero frequency and the high-pass filter has the same image impedance at an infinite frequency.

Fig. 2 shows the reactive impedances listed below for the filters. These reactive characteristics were calculated for a value of M equal

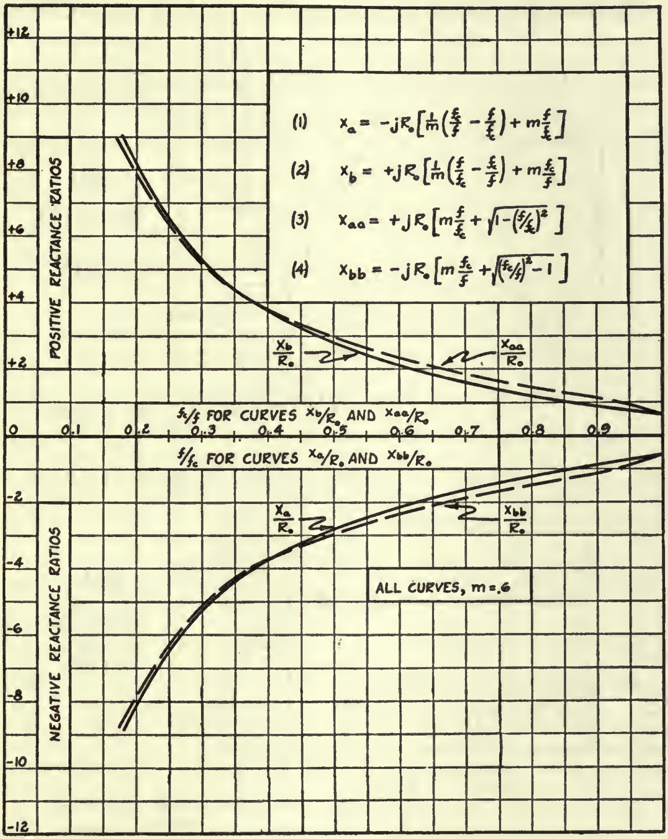


FIG. 2. Reactance impedance characteristics of networks in Fig. 1.

to 0.6, curves for other values of M not being included because of the confusion they would cause in the drawing.

(*1*) Impedance characteristic in the passing band of the coil and condenser shunted across the input of the low-pass filter, designated in Fig. 1 as X_a.

(*2*) Impedance characteristic in the passing band of the coil and condenser shunted across the input of the high-pass filter, designated in Fig. 1 as X_b.

(*3*) Image impedance characteristic in the attenuation range of the low-pass filter at the point *aa* of the filter, designated as X_{aa}.

(*4*) Image impedance characteristic in the attenuation range of the high-pass filter at the point *bb* of the filter, designated as X_{bb}.

It is seen that the reactive impedances of curves *1* and *4* are very nearly alike over the complete passing band of the low-pass filter, and

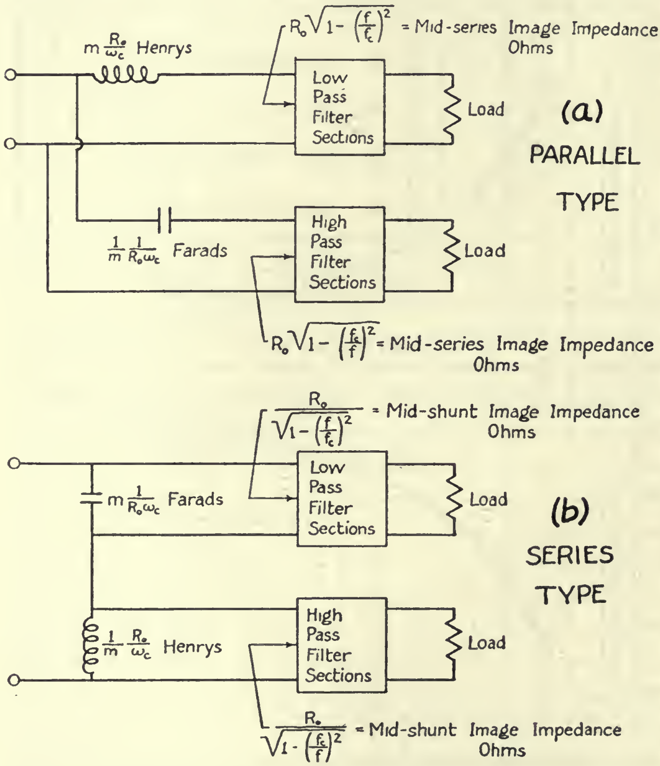
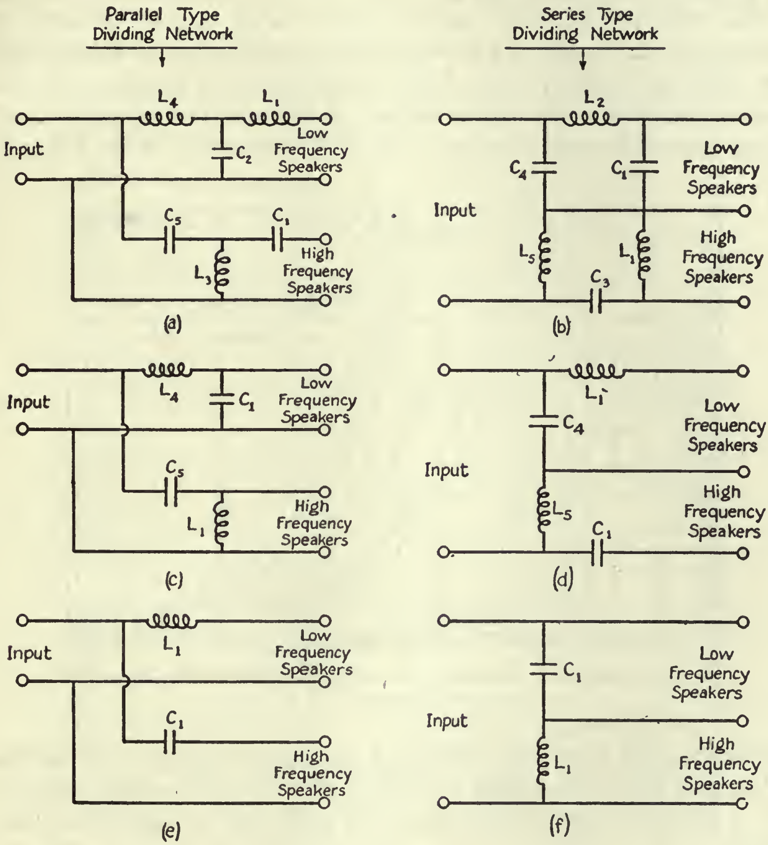


FIG. 3. Dividing networks: (*a*) parallel type; (*b*) series type.

likewise the same is true of curves *2* and *3* over the passing band of the high-pass filter. This leads to the conception of placing the two filters in parallel by omitting the shunt coils and condensers at the input ends of the filters as in Fig. 3*a*. In other words, in the passing band of the low-pass filter, the filter elements of the high-pass filter take the place of the shunt coil and condenser; and conversely, in the passing band of the high-pass filter, the filter elements of the low-pass

filter take the place of the shunt coil and condenser omitted from the high-pass filter. Then in Fig. 3*a* the low-pass unit in its transmitting range should exhibit practically the same attenuation and impedance



$$L_1 = \frac{R_0}{\omega_c} \text{ Henrys} \qquad C_1 = \frac{1}{\omega_c R_0} \text{ Farads}$$
$$L_2 = \frac{2R_0}{\omega_c} \quad " \qquad C_2 = \frac{2}{\omega_c R_0} \quad "$$
$$L_3 = \frac{R_0}{2\omega_c} \quad " \qquad C_3 = \frac{1}{2\omega_c R_0} \quad "$$
$$L_4 = (1+m)\frac{R_0}{\omega_c} \quad " \qquad C_4 = (1+m)\frac{1}{\omega_c R_0} \quad "$$
$$L_5 = \frac{1}{1+m}\frac{R_0}{\omega_c} \quad " \qquad C_5 = \frac{1}{1+m}\frac{1}{\omega_c R_0} \quad "$$

FIG. 4. Dividing network designs.

characteristics as the low-pass filter of Fig. 1, and likewise for the high-pass unit in its passing range. In the attenuation ranges of the filters the networks of Figs. 1 and 3*a* will not be respectively the same, but any lack of attenuation that the network of Fig. 3*a* has lost by

parallelling can always be made up by adding more sections in the block schematics. Fig. 3*a* then provides a method of designing the end half-sections of a low-pass filter and a high-pass filter where they are to be operated in parallel.

The same procedure as described above could be gone through for arriving at the design of a low-pass filter and a high-pass filter which are to be operated in series. This, however, is not necessary, as the series type of network can be arrived at by using the principle of inverse networks. The network of Fig. 3*b* is the inverse of the network

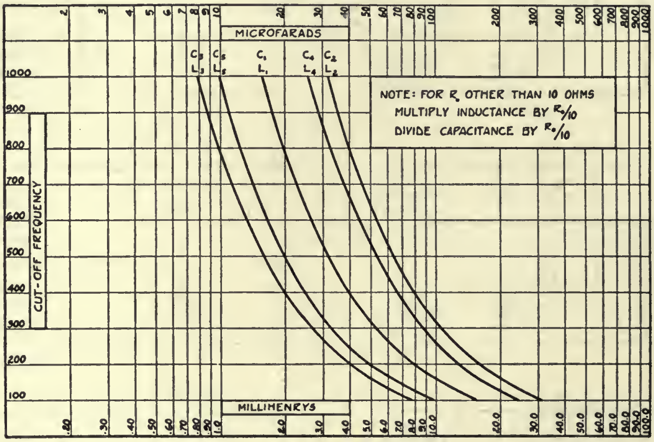


FIG. 5. Electrical constants for networks of Fig. 4: $M = 0.6$, $R_o = 10$.

of Fig. 3*a*, and represents the design procedure employed for placing a low-pass filter and a high-pass filter in series. The same value of $M = 0.6$ is, of course, used, since the networks are inverse to each other.

SPECIFIC DESIGN

The foregoing work has provided methods for designing the first half-filter sections of low-pass and high-pass filters of two-way dividing networks. As has already been mentioned, the number of filter sections that form the remaining parts of the network, as represented by the block schematics of Fig. 3, depends upon how rapidly it is desired to attenuate the suppressed frequency ranges; or, in other words, how much frequency overlap of the low-frequency range and

the high-frequency range is to be permitted. Where it is desired to secure an attenuation rate of change of about 18 db. per octave, one filter section for each of the block schematics of Fig. 3 is sufficient. Where an attenuation rate of change of about 12 db. per octave is

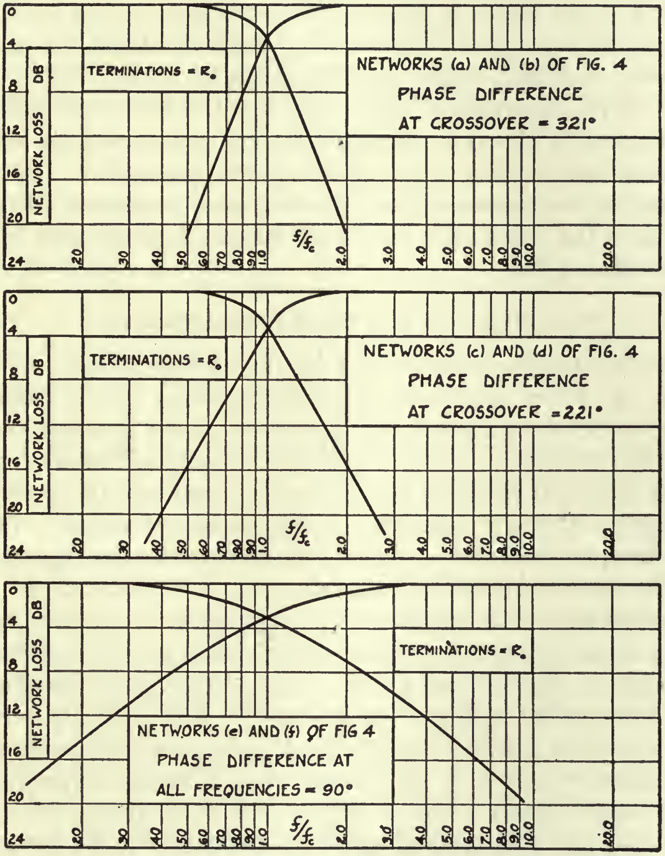


FIG. 6. Attenuation characteristics of networks of Fig. 4.

satisfactory, half-filter sections will suffice. An attenuation change rate of about 6 db. per octave can be secured by means of the end sections alone.

Fig. 4 shows six types of dividing networks, together with their design formulas, three of which are parallel types and the remainder the corresponding inverse series type. Networks *a* and *b* each contain

one and a half filter sections; that is, the half end section and one full prototype section. Networks *c* and *d* are single-section networks, and networks *e* and *f* contain only the end sections. The formulas given provide means of computing the electrical constants for any cut-off frequency, denoted by f_c, and any resistive impedance, R_o.

In Fig. 5 the values of the electrical constants for the elements of the various networks of Fig. 4 have been tabulated for a cut-off frequency of f_c and a value of R_o equal to 10 ohms. For networks *a*, *b*, *c*, and *d*, the value of M is taken equal to 0.6; whereas for networks *e* and *f*, M was made equal to zero, the reason for which is explained later, in the section dealing with impedances. For other values of R_o the values of the coil inductances increase directly with increase in the value of R_o and capacitances decrease with increase in the value of R_o.

ATTENUATION AND PHASE CHARACTERISTICS

The attenuation characteristics for the various dividing networks of Fig. 4, when operating between resistances of R_o ohms, are shown in Fig. 6. In preparing the curves it was assumed that the coils and condensers were non-resistive. In practice, where the component electrical elements contain some resistance, the curves will be slightly different, especially in the cross-over region. This, in some cases, has the effect of shifting the cross-over point slightly away from the theoretical cut-off point.

The amount of attenuation that the networks exhibit in their passing bands is especially important for high-powered sound systems. For instance, in a 100-watt system, a loss of 1 db. in the dividing network means about 25 watts' loss of power. This, it is easy to realize, is an important loss, because the final power amplifiers must supply this amount of power in addition to what is needed to produce the desired sound energy. Where care is taken to make use of low-resistance coils for the dividing network, this loss can be reduced to about 0.5 db.

In the paper by J. K. Hilliard describing the Shearer two-way horn system,[4*] it is pointed out that all virtual sources of the reproduced sound from a speaker system should coincide in a vertical plane. In arriving at the most desirable relative location for the high-range and low-range speakers to achieve this effect, it is useful to have

* See p. 45.

available the phase-shift of the dividing networks at the cross-over points. These phase shifts are noted in Fig. 6.

IMPEDANCE CHARACTERISTICS

The impedances obtained at the input terminals of the dividing networks of Fig. 4 vary, of course, from network to network. In

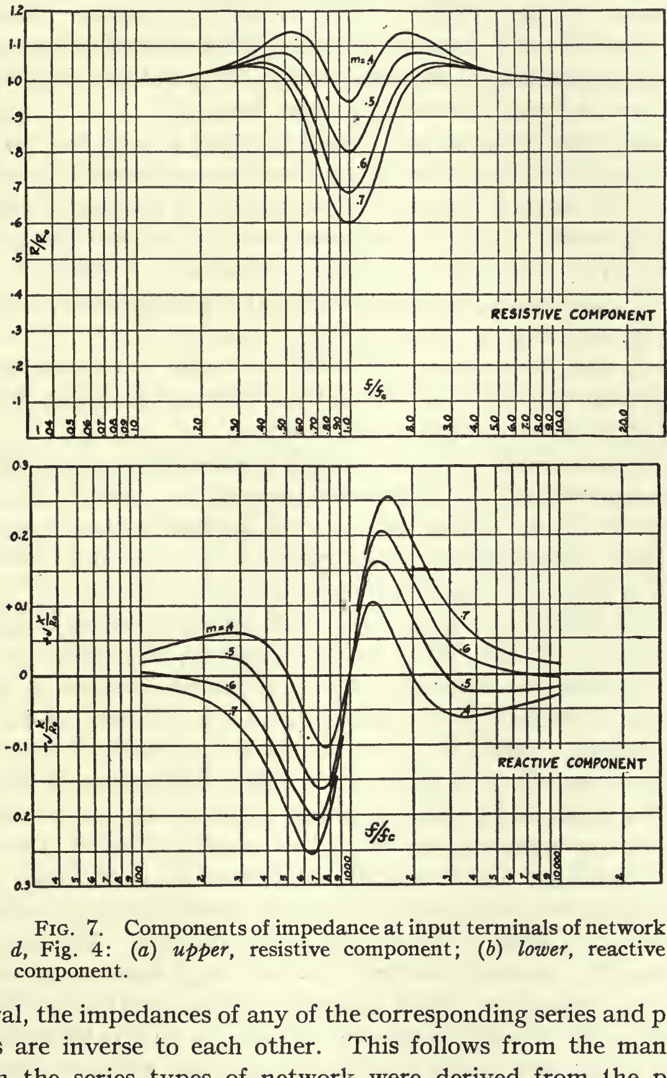


FIG. 7. Components of impedance at input terminals of network *d*, Fig. 4: (*a*) *upper*, resistive component; (*b*) *lower*, reactive component.

general, the impedances of any of the corresponding series and parallel types are inverse to each other. This follows from the manner in which the series types of network were derived from the parallel

types. In order to obtain image impedance characteristics at the input terminals of the networks, it would be necessary to use image impedance matching loads at the output terminals, as shown in Fig. 1. In practice, where the speakers are arranged in series-parallel combinations to give load resistances as closely as possible to R_o ohms at the high- and low-range output terminals, the input impedances will not adhere strictly to image impedance characteristics. However, for networks *a* and *b*, which contain a fair amount of masking because of the intervening filter sections, this change should not be great in the filter passing bands.

In connection with networks *c* and *d*, which provide less masking, it is instructive to view the input impedances obtained for various values of M and for speaker load resistances of R_o ohms. Figs. 7*a* and 7*b* give the resistive component and the reactive component, respectively, of the input impedance for network *d* of Fig. 4. It is observed that some improvement in the sending-end impedance might be obtained by using $M = 0.45$ instead of $M = 0.6$. The change in the attenuation curve which a design of this nature produces, however, is very small, and for this reason design data for such a network were not included in Fig. 5.

In connection with networks *e* and *f*, which consist only of the half-section terminations, it is necessary to employ a value of $M = 0.0$. This gives a constant input impedance of R_o ohms for load resistances of R_o ohms. The design formulas given in Fig. 4 for these networks, therefore, do not contain the parameter M.

For the designs of Fig. 4, some have mid-series image impedance characteristics at the sets of output terminals, and others are mid-shunt terminated. A feature of the mid-series termination is that the image impedance in the passing band is a resistance of R_o ohms at frequencies remote from the cut-off and gradually reduces theoretically to zero ohms at the cut-off. The mid-shunt termination, on the other hand, is R_o ohms at points remote from the cut-off and gradually increases to infinity at the cut-off. That is, these two image impedance characteristics are inverse to each other. Now it so happens that low-frequency dynamic speakers have a mechanical anti-resonance point at frequencies of 100 or lower. This results in low-frequency speakers having a relatively high input impedance at the lower frequencies which gradually reduces to the nominal impedance as the frequency increases. Hence, the writers have achieved more uniform over-all attenuation in connection with low-frequency

dynamic speakers by using dividing networks having internal mid-series image impedances at the low-frequency horn terminals. For instance, network *d* of Fig. 4 in actual operation gave better results than network *c* because of better impedance-matching conditions for low-frequency units.

CONSTRUCTIONAL FEATURES

The methods employed for assembling and wiring a dividing network may vary considerably, depending upon system requirements. In regard to the filter coils, as already mentioned, it is desirable to give considerable thought to their type and to their effective resistance. Where iron or some form of steel is used for the coil cores, modulation results if the coils are overloaded. Also, if the effective resistance is unduly large, excessive loss in the filter bands will result. The writers have found that large-size air-core coils solve the problem about as effectively as any other method.

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TELEVISION

from the Standpoint of the

MOTION PICTURE PRODUCTION INDUSTRY

Summary.—*A report of the Scientific Committee of the Research Council of the Academy of Motion Picture Arts and Sciences, Hollywood, California, May 18, 1936. Whereas excessive skepticism held the minds of those in the industry some years ago when sound was about to be introduced into the picture, now, in the case of television, instead of disbelief, we have excessive credulity. The report discusses briefly a few of the factors that would be involved upon the introduction of television, and concludes with the statement that there appears to be no danger that television will burst unexpectedly upon an unprepared motion picture industry.*

The present position of sound motion pictures, confronted by the developing art of television, differs fundamentally from the situation of silent pictures before the advent of sound. Viewed in the perspective of ten years, it is clear that before the premiere of *Don Juan* and the accompanying sound picture program at the Warner Theater in New York on August 6, 1926, all the elements favoring the transition from silent to sound pictures were present. Broadcasting had already attained a formidable place in the entertainment world, demonstrating that reproduced sound was acceptable to the public. The electric phonograph had reached a high degree of development. Public address systems had been used in the last Liberty Loan drive during the War, at President Harding's inauguration in 1921, and subsequently in national political campaigns and other events calling for the distribution of sound to large audiences. Electrical interlocks had been applied in industry, and were available for the synchronization of scene and sound. The technological obstacles had been overcome.

Yet all but a few persons in the picture business were skeptical. On the technical side, those who remembered the earlier abortive attempts to link sound with pictures ignored the recent advances in sound reproduction, although the evidences were before them. Once the technical feasibility of sound pictures had been proved, they were sure that the public did not want them. Even after the notable commercial success of early sound picture productions, this belief survived for some years.

As a result of such excessive skepticism within the industry, the transition from silent to sound pictures was hurried, disorderly, and costly. There is no likelihood of a repetition of such a crisis when television becomes a commercial factor. Instead of disbelief, we have, in the case of television, excessive credulity. Both picture people and the public have been waiting for television for five years.

Besides psychological preparedness, the preventive factors keeping television from coming unexpectedly upon our industry are the great technical and commercial complexity of the new medium, and the existence in the picture business of technically trained personnel capable of following the progress of television and of giving notice of impending developments.

Television has reached a point in its laboratory development where a small picture (about 6 by 8 inches) with moderate entertainment value, can be transmitted, but with far more complicated equipment than motion picture recording and sound broadcasting require. The cost of development up to this point may be measured in millions of dollars. Before there is any possibility of nation-wide exploitation, hundreds of millions of dollars must be expended for numerous transmitting stations of limited range, connecting cables of new design and receivers. None of these things can be attained overnight. There is a possibility that such a development may start in 1937, or more probably in 1938. It should be noted that its scope, as far as we can prevision it, is limited to home entertainment purposes in urban areas.

Barring revolutionary inventions, there is as yet no promise of the enlargement of the field of television to theater screen size, nor of an extension of the possible service area to rural districts in this country.

In the United States a start is being made in reducing television to practice in the field. A new transmitting station is being installed in the tower of the Empire State Building for an experimental service in the City of New York, to begin this fall. About 150 receivers will be furnished to selected observers. These receivers are being manufactured at a cost of probably several thousands of dollars apiece, and even upon a quantity production basis it is difficult to see how the cost of the present design could be reduced below three hundred dollars.

A new type of cable, suitable for the transmission of television images, is being installed for tests and possible subsequent commercial use between Philadelphia and New York City. Similar develop-

ments are in progress in England, Germany, France, and other countries. In 1937, therefore, considerable data should be available on points that are now obscure.

This Committee has been making a study of the technical progress of television during the past year, and possesses a general knowledge of the principal systems under development. A bibliography of the available literature has been compiled and is being kept up to date.

We shall endeavor to keep in touch with the pioneering attempts to make television a commercial reality, and as progress occurs reports will be made from time to time. Other than this no action by the Research Council of the Academy appears to be called for during the balance of 1936.

There appears to be no danger that television will burst unexpectedly upon an unprepared motion picture industry.

SCIENTIFIC COMMITTEE, RESEARCH COUNCIL

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ACTIVITIES OF SCIENCE SERVICE IN SCIENTIFIC DOCUMENTATION*

WATSON DAVIS**

Summary.—*As an aid to scientific research, Science Service has sponsored development and operation of microphotographic duplication, making available copies of books in libraries and science documents in two forms: (1) reduced-size photographic images upon standard 35-mm. motion picture film, called microfilms; (2) photoprint enlargements from the microfilms. Microfilms need optical aid in order to be read, whereas photoprints can be read with the unaided eye. Two services are in active operation: namely, the Bibliofilm Service in the Library of the U. S. Department of Agriculture, and the Auxiliary Publication Service in coöperation with editors of scientific journals. Application of microphotographic duplication to the important and complex problem of bibliography is suggested.*

The dissemination of science is of importance equal to the conduct of research. If discoveries and inquiries in the physical and natural sciences are not made known to the scientific world and the public so that they may be utilized and applied, the new knowledge might just as well not have been created.

The first step in dissemination is publication in some manner of the research results. The second step is the incorporation of references to published research results into usable bibliography. These two steps constitute the mechanism of science dissemination to the scientific world.

Realizing the importance of scientific documentation in a very broad sense, *Science Service* has been interested for the past decade in the problems of scientific publication and bibliography, urging particularly exploration of the possibilities of microphotographic duplication, *i. e.*, reduced-size photographic images of documents upon film or paper.

In 1926 Dr. Edwin E. Slosson, late director of *Science Service*, and the author, urged in correspondence, conference, and by memoranda that attention be given to the use of microphotographic duplica-

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* Presented at the Fall, 1935, Meeting at Washington, D. C.

** *Science Service*, Washington, D. C.

tion in scientific publication. Under date of August 19, 1933, the author issued for purposes of discussion and criticism a mimeographed memorandum, *Project for Scientific Publication and Bibliography*, which discussed methods of publication and bibliography, and suggested the advantages of microphotographic duplication and mechanization of bibliographic methods.

Conferences under the auspices of *Science Service* were held to discuss the proposals. Discussion and experimentation by individuals and institutions had progressed to the point in 1935 where it seemed advisable to contemplate inaugurating some of the phases of the project. Mr. Francis P. Garvan made available in July, 1935, a Chemical Foundation grant of fifteen thousand dollars for initial exploration, development of mechanisms, and inauguration of some phases of the publication project. There was therefore organized the *Documentation Division of Science Service.*

There has been considerable independent interest, principally upon the part of librarians and scholars working in the fields of the humanities and history, in the possibilities of applying microphotographic duplication to their problems. Several libraries have put into use for research purposes microphotographic duplication upon 35-mm. film. Microphotographic duplication as a means of copying and recording has been advocated and utilized in other instances. Some cameras and other apparatus for the purpose have become available commercially in America and in Europe.

Science Service is devoting the energies and resources of its Documentation Division to:

(*a*) Development of mechanisms useful in microphotographic and other photographic duplication and in bibliography.

(*b*) Publication of scientific papers and monographs that can not now win prompt or complete issuance.

(*c*) Coöperation with libraries in making available by photographic methods the literature of the past. (Bibliofilm Service, operated by *Science Service* in the Library of the U. S. Department of Agriculture.)

(*d*) Investigation of the broad problem of scientific bibliography and useful mechanisms.

MECHANISMS

It is necessary to develop camera, projection printer, reading machine, and other mechanisms of adequate design to carry out the photographic copying and publishing procedures contemplated and to allow the reading of microphotographic films. *Science Service* is

fortunate in having the coöperation of the U. S. Naval Medical School, the U. S. Department of Agriculture, and the U. S. Bureau of the Census in this development. Dr. R. H. Draeger, MC, USN, is in charge of the development of mechanisms. Dr. Draeger's original 35-mm. microphotographic camera is the one being used by the Bibliofilm Service in the U. S. Department of Agriculture Library.

The mechanisms consist of:

(*1*) Cameras for copying typescripts, books, photographs, *etc.*, upon 35-mm. film.* (In use and under design.)

(*2*) Supplementary apparatus for camera such as book-holder for camera,* film container, *etc.* (Models completed.)

(*3*) Reading machine: About the size of a typewriter, producing large-sized, easily readable images of 35-mm. microfilms. (Model completed.)

(*4*) Microfilm viewer: A small monocular optical device for reading 35-mm. microfilms a line at a time, suitable for inspecting film or for use while travelling. Will sell for about a dollar. (Design completed.)

(*5*) Projection printer: Automatic device for producing photocopies (enlargements upon paper) from 35-mm. microfilm negatives.* (Under design.)

(*6*) Developing and processing apparatus for 35-mm. microfilm and paper projection prints.* (In use and under design.)

SCIENTIFIC PUBLICATION

Scientific publication is accomplished primarily through scientific journals. The continuance of prompt, full, and economically justifiable publication is essential to scientific progress. The advance of science has brought about a multiplication of journals and increasing difficulty in maintaining their support and distribution.

In increasingly frequent instances it is impossible to arrange for prompt and complete publication of research results because of the cost of publication under the present methods. Journals find it necessary to limit the length of papers published and to reject papers that would have only a limited audience. After publication, it is often difficult to obtain a copy of a journal containing a desired paper,

* Primarily intended for use in microphotographic laboratories. Arrangements are being made for the production of these mechanisms separately or as complete microphotographic laboratories, so that libraries and other institutions can be supplied.

because of (*a*) the limited number of copies printed, (*b*) inadequate distribution of journals to libraries, and (*c*) the fact that a journal is usually "out-of-print" immediately after issuance.

For the publication of those scientific papers and monographs that can not now win prompt or complete publication, *Science Service* is offering coöperation with existing journals and societies in the following plan:

(*1*) Editors of scientific journals submit to *Science Service* those manuscripts that they find it impossible to publish promptly or completely.

(*2*) Editors would publish in their journals a notice, giving title, author, abstract, serial document number, and price, informing readers that the complete paper photographically reproduced is obtainable from *Science Service.*

(*3*) The manuscript is typed by the author upon $8^1/_2 \times 11$-inch (letter-size) paper in a standard manner for photographic publication.

(*4*) Pages of typescript would then be photographed upon 35-mm. film, which would be the master negative.

(*5*) When an order for a paper is received, its film negative is used to make a positive for distribution. The positives would be available in two forms: (*a*) Paper photographic prints made by projection, suitable for direct reading without optical aid. These would be approximately 6×8 inches, or seven-tenths the original typescript; (*b*) film positives, contact prints on film, for use in reading machines.

(*6*) A person desiring a copy of the paper or monograph would learn of its availability through the abstract published by the scientific journal thus relieved of the necessity of printing it. He would order by number, remitting the cost at the time of ordering. Each order would be filled promptly by making a photographic copy in the form desired from the master negative. Each copy would be made to order, thus obviating the necessity of keeping copies in stock, which, in the case of printed publications, requires large filing or storage space. Master negatives compactly stored as 35-mm. film upon reels, like motion picture films, would be perpetually available, and a paper or monograph would therefore never be "out-of-print."

(*7*) The cost of copies of papers would be reasonable: projection prints, 5 cents per page; microfilm, 1 cent per page.[1]

MAKING AVAILABLE EXISTING LITERATURE

Another problem confronting the scientific world is that of making available the existing literature. Only workers with access to large libraries are served with any approach to adequacy by the existing methods and resources of libraries. Even under the most ideal conditions the loan of a journal, periodical, or book to one reader makes it inaccessible to another.

Libraries have in some instances used microphotographic duplication upon 35-mm. film for making their material available, particularly manuscripts and rare books, to scholars and research workers.

The practicability of substituting microphotographic copying on 35-mm. film for inter-library loans has been demonstrated by the establishment of the Bibliofilm Service operated by *Science Service* in the U. S. Department of Agriculture Library.

The question of property right or copyright is also one that arises in connection with photocopying in libraries. This is not likely to be so important in the fields of physical and natural science as in the fields of social, historical, and economic science. Inquiries and arrangements of a practical nature have been inaugurated upon this problem. (Agreement between Joint Committee on Materials for Research and National Association of Book Publishers, May, 1935.)

TABLES OF CONTENTS AND INDEXES

As a possible useful service capable of being rendered by microphotographic duplication when reading machines are available, it has been suggested that the tables of contents of current journals could be made available at weekly or monthly intervals. It is believed that this service would call the attention of many libraries and research workers to the usefulness of many journals they do not now read, and that it would stimulate the distribution of the journals.

With the coöperation of societies and publishers, tables of contents and indexes of past volumes of scientific journals might be furnished as microfilms.

PUBLICATION OF SCIENTIFIC JOURNALS

As a possibility for the future, upon which experiments are being conducted, there is the publication of journals by microphotography. Placing a photographic image of an $8^1/_2 \times 11$-inch letter-size typescript upon an area $^1/_4$ inch or less in height is believed to be a technical possibility. A piece of film the size of a library catalog card,

3 × 5 inches, would then carry 150 to 200 pages of typescript, the equivalent of the ordinary issue of a sizable scientific journal. With the development of a suitable reading machine for these microphotographs, it would be possible to provide at a reasonable yearly subscription such a reading machine to a subscriber on a rental or time-payment basis together with the monthly issues of film carrying the images of the material being published.[2]

SCIENTIFIC BIBLIOGRAPHY

Scientific bibliography is in an unfortunately chaotic state at the present time. Some of the most important efforts toward bibliography have been suspended or are endangered (International Catalog of Scientific Literature; Biological Abstracts, *etc.*).

Bibliography must be essentially a personal service. It can hardly be expected that each scientific worker, or even each library, will have in stock all the bibliography needed upon any subject. There can be assembled in one or two places, serving the whole world, a complete scientific bibliography instantly available to provide "to-order" service. Cost of the proposed adequate system of bibliography will be far less than the present ineffective scattered efforts.

With the purpose of making available without library research any sort of references to scientific literature and bibliographies upon particular research subjects, there would be instituted and operated a bibliographical file and production service which would ideally absorb existing bibliographical schemes in all fields of science and provide bibliographical material in those fields of science that are now not easily accessible. The Documentation Division of *Science Service* is investigating and studying this matter.

For every published article, past and current, there would be as many abstract bibliography entries in a bibliographical file as there are subject classifications under which the article should be indexed. The "file" might be a roll of 35-mm. film. A complete and comprehensive scheme of numerical classification by subject would be created by utilizing existing subject classifications in science, so far as they can be utilized (International Dewey Classification?), and the creation of new subject classification schemes for unclassified areas of science. Upon each card (the word "card" is used, although the item in the bibliographical index might not be of paper material) would appear the abstract bibliographical entry and also a subject classification pictured or otherwise marked so as to actuate a selecting mech-

anism, the "eye" of which would probably be a photoelectric cell. Once these bibliographical compilations are made, this selector would pick the classifications desired. The selector would be linked mechanically to the microphotographic camera. In this way it would be possible to receive a request from a scientist for a bibliography upon a certain subject and supply it by setting the selectors to select the number corresponding to that subject classification, the camera wedded to the selector producing, to order, the bibliography desired.

By using photographic methods it would be practicable photographically to transfer to the bibliographical index these entries from past and existing bibliographies. Existing bibliographical efforts could be coördinated or absorbed to provide current and continuing bibliographies.

The bibliography thus produced would be sent to the scientist in a microphotographic form, or, at higher cost, the microphotographs could be used to produce photographic projection prints capable of being read with the unaided eye.

While the inauguration of the publication projects can be accomplished in a matter of months, the possible inauguration of a bibliographical project is a matter of years and considerable expenditure of money. Careful exploration of the bibliographical project is indicated.

REFERENCES

[1] Documents *152, 153, Science Service,* Washington, D. C.

[2] Document *46, ibid.*

SOME TECHNICAL ASPECTS OF MICROPHOTOGRAPHY*

R. H. DRAEGER**

Summary.—*Photographs are shown of a book-copying camera using 35-mm. positive motion picture film, and the special features of this camera are discussed. The problem of the reduction ratio is discussed and illustrations shown, with the conclusion that a 10 or 12 to 1 reduction ratio should be employed for book copy work on 35-mm. positive motion picture film.*

Photographs are shown of a reading machine of the author's design, and various aspects of the problem are discussed.

The rapid increase in scientific research during this century has brought about an enormous volume of data for yearly publication, the financial burden of which is now weighing heavily upon the existing scientific journals. This condition makes it desirable to find some less voluminous and less expensive method of documentation.

Microphotography offers a possible solution of the problem. Although proposed and its advantages recognized during the nineteenth century, very little use has been made of it, due to the various technical difficulties that beset the art.

The excellent progress in preparing fine-grained emulsions makes it possible to copy printed matter in reduced form, duplicating it photographically to a degree of perfection depending upon the quality of the apparatus used and the reduction ratio employed.

In 1932 the author undertook the design and construction of a camera suitable for copying the printed pages of books on positive motion picture film. The camera was completed in 1934, and at the present time is being used to operate the Biblio-service of the Library of the U. S. Department of Agriculture. A newly designed camera is nearing completion at the Navy Medical School, a model of which is also being constructed for the Library of Congress. This camera has a film capacity of 1000 feet, automatic focusing, and automatic timing. Completely automatic action has been provided for copying

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* Presented at the Fall, 1935, Meeting at Washington, D. C.

** Lieutenant, Medical Corps, U. S. N.

loose sheets or cards which may be readily fed beneath the camera. Provision has been made to use either 35- or 16-mm. film, and in the case of the model for the Library of Congress 70-mm. film may also be used.

Fig. 1 is a view of the original camera, mentioned above, and shows the principal features that have been incorporated into its design. The apparatus consists of a table, a supporting rod, a camera support arm, the camera, a book holder, and lighting, indexing, and timing

FIG. 1. Original book-copying camera.

mechanisms. The camera proper hangs vertically downward, its lens pointing toward the book below.

The book is placed upon a special support which automatically centers it and keeps it in the proper position against a counterbalanced hinged glass plate which rises automatically at the end of each exposure. The glass plate is in the focal plane of the lens when in a horizontal position and maintains the book pages in proper focus. The two open pages of the book are photographed simultaneously and appear upon the film as shown in Fig. 2.

The lights consist of two banks of lamps which are turned on and off with each exposure. The indexing of the film and timing of the exposure are accomplished automatically. The lens used is a Zeiss

Tessar $f/6.3$, $3^1/_2$-inch focal length. The magazine capacity is 150 feet of 35-mm. motion picture film. Positive film is used, because it has good contrast, fine grain, and is considerably cheaper than the negative stock.

The operation of the camera is simple. The operator places the book upon the book holder and adjusts the platens to the proper height to accommodate the thickness of the particular book. He then measures the height of the book pages in inches and sets the camera support arm at the proper height and the lens spiral for the proper focus. The scales for these two settings are marked to correspond with the book height in inches so as to produce an accurately focused image completely filling the frame of film to be exposed.

The hinged glass cover is then pulled down to a horizontal position

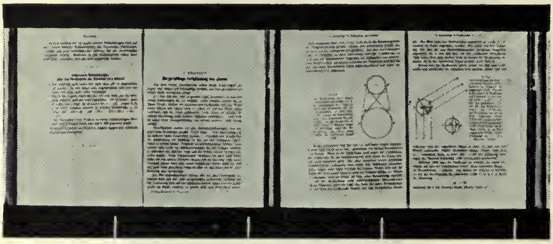

FIG. 2. Strip of motion picture film having a book-page image on each $^3/_4 \times 1$-inch frame.

over the first pages to be copied. This closes a contact which turns on the lights and opens the lens shutter. At the termination of the exposure, the lights go out, the shutter closes, and the hinged glass book cover is tripped and returned to the raised position. The operator turns to the next page to be copied, and repeats the procedure for as many pages as are to be copied. Since two open pages of a book are copied simultaneously, a speed of 1000 pages per hour is easily attained.

Figs. 3 and 4 are views of the reading machine, which is of the translucent screen variety. The screen is arranged at a comfortable reading angle before the reader. The lamp house and indexing mechanism are carried upon a rotatable head above the screen. Turning from page to page is accomplished by the simple movement of either small hand-crank on the head. The film is loaded into the machine without any threading operation.

The film gate consists of two parallel plates of glass, one stationary and one hinged. The hinged plate is so arranged that it opens before the film is moved in either direction so that the film moves only through an open slot. The arrangement mentioned above has been found to be the only satisfactory method of holding the film in a plane for critical projection. A film gate consisting of an aperture plate allows slight bending of the film and consequent loss of detail in the projected image. A special feature of the device is its rotatable head,

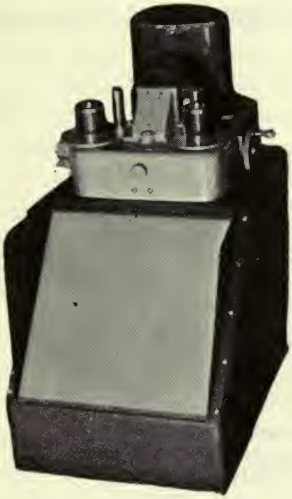

FIG. 3. Reading machine, translucent screen variety.

FIG. 4. Reading machine, showing 90-degree rotation of the head.

which enables images placed upon the film in any orientation to be read.

Let us now consider other problems in connection with microcopying. The reduction ratio employed depends upon the resolving power of the film and the use to which the copy is to be put. If the copy is for record purposes and to be filed for occasional use only, a higher reduction ratio is justified. If the material copied upon the film is primarily intended for reading or reproduction, the reduction ratio should be such that the original and copy will have similar appearances when the copy is enlarged to the size of the original. This is necessary if ease of reading is to be enjoyed and eye-strain avoided.

The reduction ratio which will afford this result is a controversial point. Obviously, the greater the reduction ratio the less the cost and the greater the saving in storage space. However, this is not the only consideration, and should not be allowed to overbalance the issue.

In order to test the resolving power of the film used in the above-described camera, a test screen (Fig. 5) was made and uniformly illuminated. The screen was originally drawn to a large scale, and then reduced photographically to approximately 20 millimeters square on a lantern-slide plate. The lines on the lantern-slide screen were separated by a distance in microns equal to ten times the number shown to the right of each of the eight squares. Thus when

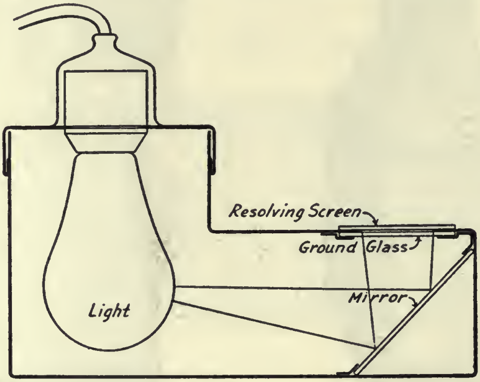

FIG. 5. Apparatus for testing resolving power of film for micro-copying camera.

the screen is photographed upon the motion picture film at a reduction of 10 diameters, the numbers designate the microns of separation of the corresponding lines. By making exposures with this device in various positions, images were placed at several points over the film gate area.

The film was then processed and studied under the low-power microscope, whereupon it was easily ascertained which of the lines were resolved. Using an elon-hydroquinone developer, the 25-micron lines were readily resolved over the entire film aperture. By using special precautions, fine-grain development, and employing the center of the field only, the 15-micron lines were discernible.

This apparatus has proved to be useful in checking not only the resolution of the film, but the focus of the lens and the effect of the lens apertures, and the definition of the lens may likewise be de-

termined by having one factor variable and keeping the other constant. The depth of focus may be easily determined by making a series of exposures at slightly increased and decreased distances from the focal point of the lens.

Fig. 6 is a photomicrograph of a few letters from a film copy of a printed page made at a reduction ratio of 10 diameters. It will be seen that the silver grains are readily seen but that the letters are also clearly legible. At higher reduction ratios the graininess of the film becomes more apparent.

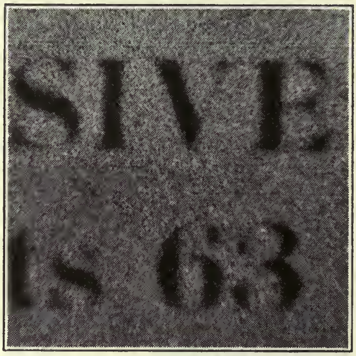

FIG. 6. Photomicrograph of film copy of printed page (x 10).

At a reduction ratio of 10, photoprint reproductions may be made from films that resemble the original very closely. As finer-grained emulsions are developed, higher reduction ratios may be employed. However, if satisfactory results are to be attained, the reduction ratio should not exceed a definite relation to the resolving power of the film.

It is hoped that this important point will be kept in mind by those engaged in microphotographic work in order that the public appreciation of this new and promising field may not be stifled by imposing too great a hardship upon the reader.

MICROFILM COPYING OF DOCUMENTS*

T. R. SCHELLENBERG**

Summary.—*Microphotographic duplication peculiarly fits the research needs of modern scholarship for the following reasons: it reduces the bulk of records in the same geometric ratio in which they are accumulating; it makes them as permanent as they are now ephemeral; it makes them mobile, permitting a more widespread use of them; it makes it possible to supply records for specialized use; it facilitates the co-operative exploitation of records that have become so extensive that they can no longer be mastered individually; and it permits a more exact and accurate use of records.*

During the Franco-Prussian war, a photographer within the beleaguered city of Paris developed a means of copying messages upon film to be transmitted by carrier pigeons to anxious compatriots in the provinces. About 115,000 such dispatches were sent to and from the city during the siege. After the war the process of making microfilm copies of documents was described in a pamphlet, in which was inserted a specimen of the rolls of film that had been produced. Sixty-four years later this film was discovered by Dr. Bendikson in the rare collections of the Huntington Library. Dr. Bendikson made an enlarged print of the film, which he reproduced in the February, 1935, issue of *The Library Journal.* The document, which had been copied at a reduction of 32 diameters, was quite legible after the lapse of more than half a century.

Little progress was made in copying documents upon film until another great emergency. During the World War, German military authorities made extensive use of photographic equipment for copying military secrets. A German scholar, following in the wake of the Austrian armies, also made use of the process for copying historical documents. In the *Minerva-Zeitschrift* for 1930 he describes how, over night in a dingy room of a monastery in the Albanian mountains,

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* Presented at the Fall, 1935, Meeting at Washington, D. C.

** *Executive Secretary,* Joint Committee on Materials for Research, of the American Council of Learned Societies and the Social Science Research Council, The National Archives, Washington, D. C.

he made copies by means of a Leica camera of a whole body of valuable papers that were destroyed soon thereafter.

Just as micro-copying peculiarly met the needs for the reproduction of documents in the special emergencies that I have just indicated, so microphotographic duplication will fulfill the research needs of present-day scholarship. There are several reasons why this is the case. By microphotographic technic I simply mean making a film copy of a document, which is to be read not by making enlarged prints from it, but by throwing the image of the film by means of a projector or reading device upon a surface from which it is to be read.

The first reason is this: micro-copying offers a means of reducing the bulk of documents in the same geometric ratio in which their bulk has been increased. With the complexity of our life has come a proportionate increase in the quantity of records pertaining to its activities. So great is the increase that the depositories of such records are faced with the prospect of doubling their capacity every decade. By resorting to micro-copying, however, the ever-increasing accumulation of modern materials, which threatens to stultify our present research methods, can be brought under control. By photographing at a reduction of 16 diameters, newspapers, for example, are being reduced by means of the Recordak machine developed by the Eastman Kodak Company, to a surface occupying $^1/_{256}$ the original area. It is likely, then, that bulky materials like newspapers, large series of schedules like those accumulated by the Census Bureau and other units of government, transcripts of hearings like those held before the NRA and AAA, in fact, any large rational series of documents, which has no intrinsic historical interest but which should be preserved for the information it contains, may, in the future, be copied upon film for the conservation of storage space. The great mass of records that constitute the evidences of the New Deal may have to be filmed so that it is possible to administer them. The point is soon reached when it becomes cheaper to film the documents than to provide storage space for them.

Just as the quantity of records has increased in geometric proportions, so the records have become constantly more ephemeral in character, both because of the quality of their content and because of the quality of the material upon which they have been produced. This fact makes apparent the second reason why microfilm copying is peculiarly suited to fulfill modern research needs. While the permanency of films is still an open question, which fortunately

will be answered as a result of the study of film stability being made by the National Bureau of Standards, there is no doubt that filming is the only possible means of preserving many of the newspapers issued on wood-pulp paper and many of the government serials issued by the Latin-American and European countries. Furthermore, in business and governmental work there are being created great masses of documents that serve only temporary purposes, but which throw very great light upon the operation of both business and government. Such material constitutes the raw-stuff for research in the social sciences. It is material that is so unorganized that it is not fit for publication in its present form, but also is so rich in informational content that it should not be destroyed. Among such records, for example, are the foreign cable dispatches of news agencies like the United Press and the Associated Press, ordinarily kept for two years, after which the statute of limitations removes the danger of libel suits. Such records can be preserved cheaply in film form, though the preservation of the originals would be an impossibility.

The third reason why microfilm copying peculiarly meets the needs of modern scholarship is that it renders research materials mobile. It was for this very reason that documents were filmed during the Franco-Prussian War and the World War. The films could be carried by the wings of carrier pigeons. It is conceivable that the cost of producing microfilm copies of documents will be brought to so low a level that it will be less than the cost of mailing the original as an inter-library loan. The most conspicuous attempt to replace inter-library loans with film copies is that made by the Department of Agriculture library. When large depositories have the equipment for producing, and small depositories the equipment for reading film copies, the library resources of the country will become fluid. Effective research will be possible in small research institutions throughout the country, and scholarship will become far more democratic in its workings.

Not only will the introduction of microphotographic technic render the existing research materials more accessible, but it will also permit the reproduction of highly specialized materials for the specialist. This is the fourth reason why film copying meets the needs of present-day scholarship. It arises from the fact that micro-copying is the only economical method of reproducing documents in which minimal unit-costs can be achieved in very small editions.

This practically brings a return to the conditions subsisting prior to the time when Gutenberg developed printing from movable type, when it cost no more for scribes to make unique copies of a book than to make many copies. Material for which there is a demand by only a few scholars might just as readily be made available in the form of micro-copies as material demanded by the many.

A fifth reason for the inevitable acceptance of microfilm copying is that it facilitates the coöperative exploitation of research materials. The records pertaining to social movements have become so extensive that they can no longer be mastered individually. In the bibliographical field, for example, there have arisen innumerable specialized bibliographies, so great in number that the use of them is almost as difficult as the use of the original references without bibliographical aids. Certainly research would be facilitated if, instead, master card bibliographies were complied through coöperative effort, of which periodically film copies could be made to be distributed among research institutions. Likewise, microfilm copying can be utilized to advantage in compiling union and regional lists of library holdings or in compiling a union list of historical manuscripts in this country.

A sixth reason for the use of microfilm copying in research is that it permits more exact work. A scholar using a camera like that developed by the Folmer-Graflex Corporation can copy manuscript and reference materials more extensively and quickly, allowing him to make more accurate quotations and citations, more prolonged study, and more exact collations of the records on a given subject.

The wide application of micro-copying to the research problems of modern scholarship is an inevitable development. It reduces the bulk of records in the same geometric ratio in which they are accumulating; it makes them as permanent as they are now ephemeral; it makes them mobile, permitting a more wide-spread use of them; it makes it possible to supply records for specialized use; it facilitates coöperative exploitation of records that have become so extensive that they can no longer be mastered individually; and it permits a more exact and accurate use of records. As the wells of financial support for learned institutions run dry, a technic will be employed that will make possible the accomplishment of the present objectives of scholarship with the expenditure of less money.

DISCUSSION

MR. BRADLEY: I think a word of explanation is due the Society this morning. I suggested that this subject be brought up for your consideration largely as a matter of disposing of it. It has been pointed out this morning that there may be a parting of the ways on sizes, dimensions, and technic in this activity from the activities of motion pictures. Frankly, the source of material is about the only thing I see now that we have in common. That it will become a new and major industry there is no doubt in my mind.

Mr. Schellenberg and the others have cited source material of a magnitude that is almost staggering. I want to cite one other instance, in connection with the National Archives, which I have the honor to represent. In 1930, a committee was appointed to make a survey of the mass of documents and records in the possession of the Federal Government and the rate at which it was accumulating. At that time it was accumulating at the rate of 200,000 cubic feet annually. Under the present administration with our new bureaus and additional functions of government, the rate of increase must be considerably higher. What it is I do not know.

There is a committee of Congress called the Committee on Disposal of Executive Papers, but altogether there are some fourteen laws governing the disposal of various Government papers. There is considerable variation and often confusion in the routine of such disposition. For example, last year, if I remember the figures correctly, the Treasury disposed of ninety-seven tons of papers as waste. Sometimes it is burned, sometimes sold as waste, sometimes it is so mutilated that it can not be read or used commercially.

It is thought that if the Bureau of Standards reports favorably upon the life of microfilm, The National Archives might reproduce (as a policy of recording) this great mass of material into the microfilm form so that the evidence of the originals would be preserved even though the physical body should be disposed of. A wild guess indicates that we alone might copy some 5,000,000 items annually, or half a million feet if we use the motion picture film. But whether or not this is a problem for the Society of Motion Picture Engineers, I do not know. Not only standard simplified practice, not only a study of film, but a study in nomenclature seems to be quite appropriate.

MR. MITCHELL: It may be of interest to mention the fact that the University of Chicago has finished photographing papers dealing with the NRA hearings. I do not know the exact figures, but if I recollect correctly, the original would be about 1000 volumes of 500 pages each, so you can appreciate the magnitude of that one particular task.

MR. FAMULENER: Have any particular methods of processing been developed with a view to minimizing the grain and increasing the reduction ratio that may be used?

MR. BRADLEY: There is a study on foot; in fact there are several studies, and the Carnegie Foundation and the National Research Council have made studies on the preservation of film. The advisory committee created by the National Research Council is acting as a proponent committee on simplified practice in which the ratio of reduction will be studied among other things.

MR. CRABTREE: There has perhaps been a tendency in our Society to overstress sound in the past and underestimate the importance of the picture. This par-

ticular work consists in making pictures on motion picture film, although the result attained is certainly not a moving picture. However, I do not see why the subject is not cognate to our interests.

With regard to the question of whether 16- or 35-mm. or wider film will be adequate, I should say that with expected improvements in emulsions and methods of producing fine-grained images, it will probably not be necessary to go to film larger than 35-mm.

MR. TASKER: It might also be interesting to add that the very requirement of finer grain, which seems so desirable for this purpose, is equally desirable for the motion picture art, and hence developments in the one field are apt to aid those in the other.

NEW MOTION PICTURE APPARATUS

During the Conventions of the Society, symposiums on new motion picture apparatus are held, in which various manufacturers of equipment describe and demonstrate their new products and developments. Some of this equipment is described in the following pages; the remainder will be published in subsequent issues of the Journal.

NEW BACKGROUND PROJECTOR FOR PROCESS CINEMATOGRAPHY*

H. GRIFFIN**

A new type of background projector for use in process photography in motion picture production studios has been developed which has already been installed in studios in England, Sweden, Japan, and the United States (Figs. 1 and 2).

In appearance this equipment is quite similar to the well known Super Simplex projector, but the mechanism, magazines, and lamp house are mounted upon a specially built, rigid pedestal assembly in order to eliminate the possibility of vibration during operation (Fig. 3). The complete unit is composed of a specially constructed Super Simplex mechanism, the usual upper and lower magazines, and a Hall & Connolly super-high-intensity lamp and lamp house, all mounted upon the above-mentioned pedestal. The projector mechanism is built especially for the work it must do, and commercial tolerances acceptable for theater projection are eliminated in the construction of the process projector. The film-trap, for instance, is very accurately constructed, and is equipped with edge-guiding means in order that the picture may be absolutely steady laterally, and provision is made in the film-trap design and construction for judging the projected picture to determine what causes any unsteadiness that might be present.

For example, with this equipment it is possible to project a sprocket hole in the film, and if the perforations in the film are accurate—and they usually are—the image of the sprocket hole upon the screen is absolutely steady, both laterally and vertically. If the negative is projected and the camera frame line moves with relation to the perforation, that is a definite indication that the camera movement is not steady. If the positive is projected and the positive frame line moves with relation to the sprocket holes, that is a definite indication that the camera or the printer was unsteady, so that it is possible to observe and analyze satisfactorily any defect that may be present in the master print for process projection and thus eliminate endless discussion as to where the fault resides.

The intermittent movement of this particular equipment is of the Geneva type. It is manufactured to practically zero tolerance, and steadiness of the movement is carefully checked with a special test-film.

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* Presented at the Spring, 1935, Meeting at Hollywood, Calif.

** International Projector Corp., New York, N. Y.

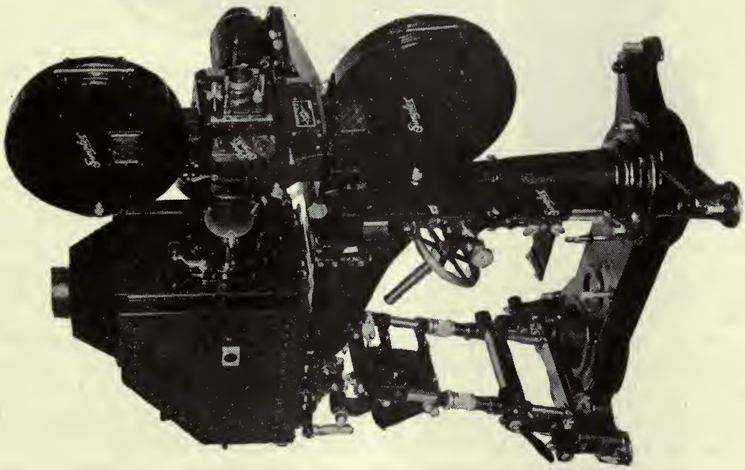

FIG. 1. Background projector; operating side.

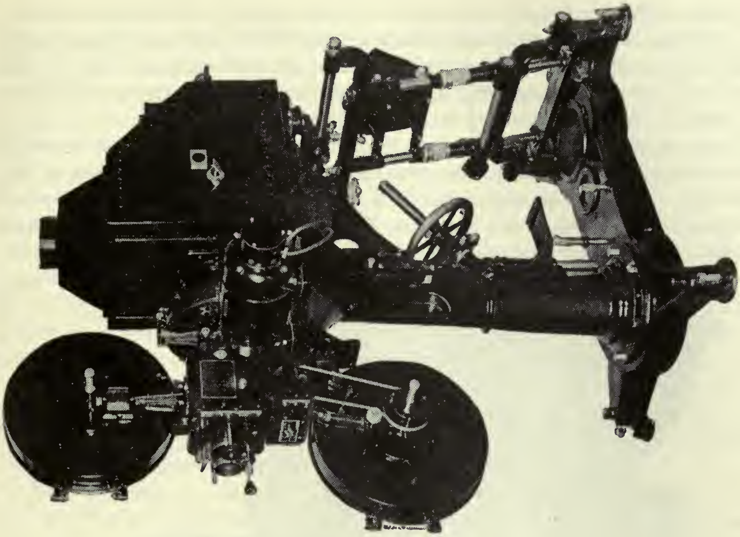

FIG. 2. Background projector; non-operating side.

The mechanism may be easily lubricated without opening any of the mechanism doors. The bearings are fed through oil-tubes reached from the top of the mechanism with the exception of the bearing for the intermittent movement, the oil-tube for which may be seen through a hole in the door on the non-operating side of the mechanism at a certain position of the framing device.

The lower section of the upper door on the non-operating side of the mechanism has been removed, thus making it possible to remove the door after removing the hinge screws. Thus it is possible to get into the non-operating side of the mechanism should it become necessary to do so. The lower door section may be removed in the same manner. A grease cup is provided for lubricating the rear shutter

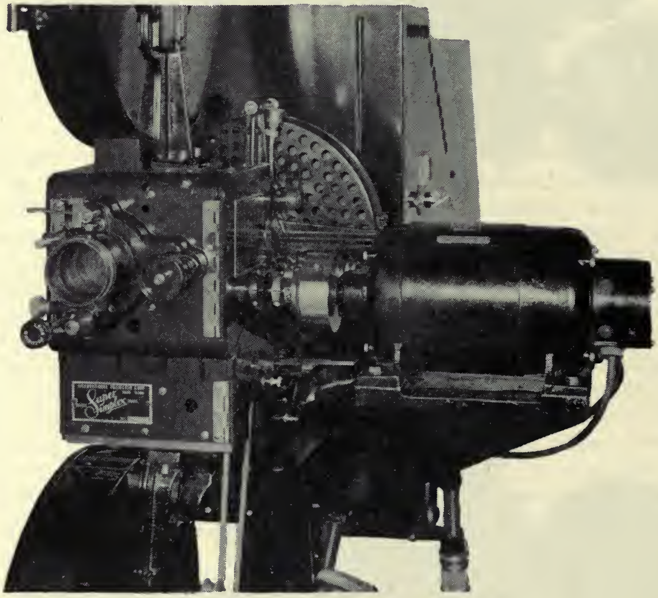

FIG. 3. Background projector; pedestal assembly.

shaft, a single turn of which suffices to force sufficient lubrication into the ball bearing. A special lubricant has been developed for this purpose.

No motors are supplied as part of the equipment, for the reason that various types of motors are used throughout the world for interlocking systems. A kind of motor used on the customer's particular type of interlocking system is furnished to the projector manufacturer, and a special motor table is then designed and built and rigidly attached to the projector stand in such a position that the motor shaft is coupled directly to the drive shaft of the intermittent movement. Lost motion is therefore eliminated between the camera shutter and the projector shutter, since no gear train is involved in this form of design.

The intermittent movement of the projector, as is the case with the camera, when properly interlocked operates at 1440 frames per minute—standard photographing and sound recording speed. Adequate provision is made to adjust the projector and camera movements to the interlocking motor system. The coupling flange on the intermittent movement is so designed that it may be secured to the shaft in any position. It is necessary only to open two clamping screws, rotate either the motor or the intermittent movement shaft while the one or the other is standing, and clamp the flange tightly again after the proper position is attained in synchronism with the camera shutter movement.

As in the case of regular projection room practice, it is necessary to adjust the lamp house to its correct position with relation to the aperture plate of the projector, to see that the special condensing system is in its proper relative position, and that the arc is burning at its proper capacity in order to clear up the entire screen and attain satisfactory and uniformly distributed screen illumination. If a "hot spot" occurs at the center of the screen, it is possible to remove it by mounting a small circular disk cut from fine copper mesh exactly in the center of the light-beam at the proper point in front of the lens. Experiment will definitely determine the distances required with lenses of different focal lengths.

There is, of course, very noticeable flicker upon the screen when using this type of projector, due to the single-bladed shutter that is used, so that it should not be used for normal projection of motion pictures. It is purely for process work, and, naturally, flicker is not noticeable to the synchronized camera under such circumstances. Should it be required to project standard motion pictures with this equipment, the shutter must be removed and the standard two-bladed shutter substituted. The equipment, of course, must be carefully handled, due to its extreme accuracy, and if expert attention is given it, it will give excellent service for an indefinite period of time.

RCA PHOTOPHONE HIGH-FIDELITY SOUND REPRODUCING EQUIPMENT*

J. FRANK, JR.**

In February, 1931, RCA Photophone introduced the first theater sound reproducing equipment operated entirely by alternating current. The rotary stabilizer sound-head attachment was introduced in December, 1932. Consistent development in the past four years in the improvement of reproducing apparatus has made possible the high-fidelity equipment.

Improvements in sound-film recordings during the past year and planned for the near future require reproducer equipments having increased reserve power output for satisfactory results. To meet these requirements a new line of high-fidelity sound reproducing equipment has been introduced. Considerably in-

* Presented at the Fall, 1935, Meeting at Washington, D. C.

** RCA Manufacturing Co., Camden, N. J.

creased output, equivalent performance at lower cost, greater flexibility, and easier operation are all factors involved. The equipment is designed to reproduce class *A* release prints (certain producers release class *A* and class *B* prints, the former with a reduced recording level permitting extended volume range) satisfactorily in auditoriums of all sizes. The high-fidelity equipment is offered on an outright or conditional sale basis.

High-fidelity equipments are available with either a combined sound projector or with sound-head attachments for mounting with silent projectors. The sound projector is equivalent in performance to the Super Simplex silent projector. All the outstanding features of the high-fidelity sound-head attachment have been incorporated in this projector.

The sound projector and sound-head attachment employ a combined freely

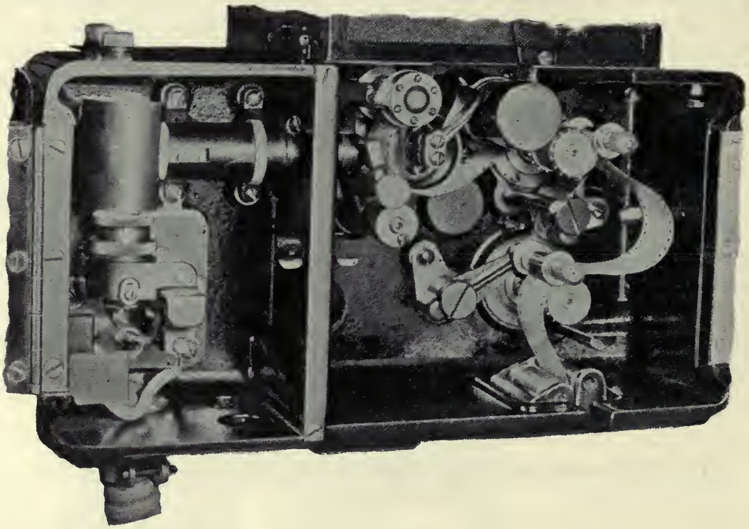

FIG. 1. Operating view of rotary stabilizer sound-head attachment.

revolving gate and rotary stabilizer to maintain constant speed of the film past the scanning light. Driving motors for all forms of power supply are readily interchangeable. The use of precision ball bearings throughout provides a construction that is trouble-free and has very long life.

The projector is available with a built-in incandescent lamp house for a 900- or 1000-watt lamp, a 30-ampere low-intensity reflector arc lamp house, or a 45-ampere high-intensity reflector arc lamp house. Power conversion apparatus is also available at additional cost. In addition to the built-in lamp house, other features include a motor, built in for quiet operation, gear drive throughout, 2000-ft. magazines, and a 3- or 5-point pedestal base.

All amplifiers are a-c. operated. Each unit is self-contained, with its own power supply unit. Standard RCA Radiotron tubes are used throughout. Amplifiers are designed for uniform reproduction of 40 to 10,000 cycles per second,

with means for adjusting the response characteristic to compensate for auditorium conditions and poor recordings.

These equipments all employ separate voltage and power amplifier units. From several points of view, this is desirable. The voltage amplifier unit has sufficient power to overdrive the power amplifier, without appreciable distortion from the amplifier unit. If for any reason the power amplifier should fail, operation can be temporarily continued with the voltage amplifier unit alone. If there are, in the future, any marked improvements in the methods of recording, necessitating either extension of the frequency range or the need for increased power output, units can be added to or substituted for the present ones.

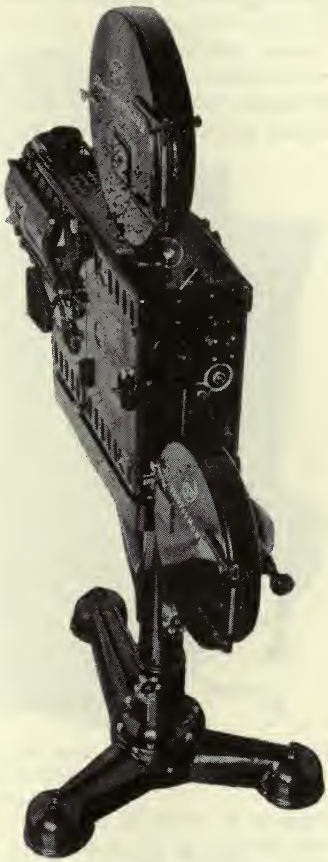

FIG. 2. RCA Photophone sound projector.

The amplifier units are designed for shelf mounting; in a wall cabinet for the smaller equipment, and on standard channel-iron racks for the larger equipment. In the latter case, all the power equipment is mounted upon the rear panel, while the parts comprising the amplifier circuits are mounted upon a hinged shelf protruding in front of the rack. The hinged shelf feature permits easy access to all parts without the necessity of removing the unit from the rack. It also permits easy removal of the amplifier circuit portion alone. Capacitors are sectionalized and separately fused, which means that the failure of any one section will not cause sound "outage," but will merely cause slightly increased hum. The failure of the fuse can easily be determined by the operator. These units also include neon indicator lamps in the plate circuits of the tubes for assistance in determining the cause of failure of operation. Perforated panels are employed in front of amplifier tubes to permit quick inspection.

The larger equipment employs a low-impedance photocell coupled circuit, permitting locating the amplifier at some distance from the projector. The small equipment employs low-capacity coupling, requiring mounting the amplifier upon the wall between the projectors. Changing over the amplifier input from one projector to the other is accomplished by a switch located upon the front wall at each projector station. With the larger equipment, provision for variable control of the photocell output level is also provided. A remote volume control device is available for the larger equipment at additional cost.

A separate tube rectifier for supplying power to the loud speakers is furnished in a wall-mounting cabinet for location in the rheostat room. This unit furnishes d-c. excitation to a maximum of five speaker units upon the stage as well as current for the exciter lamps. In the smallest equipment, a-c. exciter lamps are used and speaker field excitation is derived from the amplifier circuit. For operation by direct current, rotary converters and starters can be supplied.

Loud Speaker Equipment.—The loud speakers are of the directional baffle type, with dynamic cone reproducing units. For the larger equipment a combination of straight baffle loud speakers for reproducing a range of 125 to 10,000 cycles per second and a folded baffle loud speaker for reproducing frequencies of 40 to 125 cycles per second are furnished. The straight baffle loud speakers employ a 6-inch dynamic cone unit. For large auditoriums, three or six are used, depending upon the size and shape of the auditorium. The low-frequency folded baffle loud speaker employs two 8-inch dynamic cone units. This combination of loud speakers has an over-all depth of only 26 inches, and can be flown with the picture screen or mounted in a cage on a monorail.

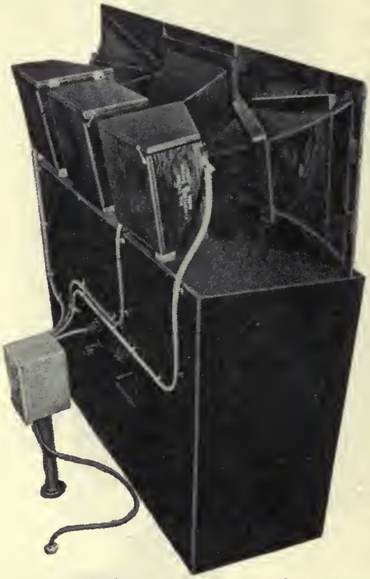

FIG. 3. Triplet and low-frequency loud speaker combination.

The high efficiency and directional characteristics of the loud speakers make it possible to cover the auditorium uniformly, with minimum reflection from walls and ceiling. An electric circuit cutting off the response of the low-frequency loud speaker below the range of the fundamental voice frequencies assures satisfactory intelligibility.

A compound directional baffle loud speaker, employing a single 6-inch dynamic cone unit, with an over-all depth of 21 inches is used with the medium-size equipment. Extended-range reproduction is attainable with this single loud speaker, which employs a straight horn for reproducing the high frequencies and an exponential horn for the low frequencies.

A straight directional baffle loud speaker, employing a single 6-inch dynamic cone unit, having an over-all length of 37 inches, is furnished with the smallest equipment. A short metal directional baffle loud speaker, employing a permanent field dynamic cone unit with a separate volume control, is furnished for monitoring purposes in the projection room.

Portable Sound Equipment.—This consists of one or two portable sound projectors, a portable amplifier, and a portable loud speaker. The single projector equipment consists of three cases; one each for the projector, amplifier, and loud speaker. The double projector equipment consists of five cases, one each for two projectors, amplifier, loud speaker, and second upper magazine.

Portable Sound Projector.—The portable sound projector is available with either an incandescent lamp house for a 900- or 1000-watt Mazda lamp, or with a 15-ampere, low-intensity reflector arc lamp. An a-c. exciter lamp is employed. Projectors are regularly furnished with a standard series *1* Bausch & Lomb 5-inch projection lens. Portable projector stands are available at additional cost. The

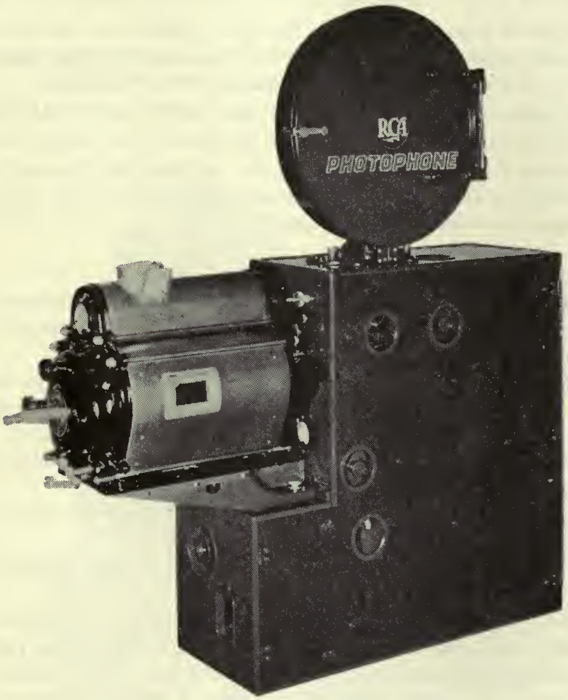

FIG. 4. RCA Photophone portable projector with 15-ampere arc lamp.

over-all dimensions of the projector are $43^1/_2 \times 13 \times 44$ inches; weight, approximately 106 or 129 pounds.

Portable Amplifier.—The portable amplifier consists of a voltage amplifier unit and power amplifier unit neatly mounted in a carrying case in such a manner that all controls are readily accessible. Two receptacles are provided for the output of each projector. A jack is provided for a close-talking microphone or a phonograph.

The amplifier units are similar to those furnished with the *PG-90* equipment. A tone control is included, for modifying the response. A 10-ft. power cable is furnished. The complete assembly of amplifier in case measures $18 \times 19 \times 11$ inches, and weighs approximately 52 pounds.

Portable Loud Speaker.—The portable loud speaker consists of an 8-inch dynamic cone speaker unit mounted in a carrying case of such construction that it acts also as a baffle. Included in the case is a wooden reel which carries 100 feet of loud speaker cable, and provision is made also for carrying one 2000-ft. upper projector magazine. The completed unit is of very rigid construction, and capable of handling the power output of the amplifier adequately. The unit in the case measures 20 × 19 × 12 inches, and weighs approximately 47 pounds.

Upper Magazine Case.—For double projector equipment, the second 2000-ft. upper projector magazine is furnished with a separate carrying case, measuring $17^3/_4 \times 18^1/_{16} \times 8$ inches, and weighs approximately $20^1/_2$ pounds.

Public Address and Sound Reënforcing System.—The use of public address and sound reënforcing systems in theaters is becoming increasingly more gereral. The high degree of perfection attained in the presentation of sound motion pictures has created a public demand for greater perfection in the presentation of both stage shows and orchestral selections.

RCA sound systems provide all the following facilities:

(*a*) Sound reënforcement of stage program, involving installation of microphones in footlight trough, upon the stage, and in the orchestra pit, with loud speakers at the side of the proscenium arch.

(*b*) Sound reënforcement of vaudeville performance or vocal solo, involving installation of one or two microphones upon the stage or upon the organ console near the soloist, with loud speakers at the side of the proscenium arch.

(*c*) Public address system for announcements, with microphone located in manager's office, loud speaker in auditorium.

(*d*) Rehearsal address system, with microphone at director's position and permanent or portable loud speaker upon the stage and in booths.

(*e*) Stage manager's call system, with microphone at stage manager's position, and loud speakers in dressing rooms.

Two portable public address equipments are available. The larger includes a velocity microphone with desk stand and suitable amplifier in one carrying case, and two portable loud speakers in second carrying case. The smaller includes a carbon microphone, amplifier, and loud speaker in a single carrying case.

RCA Sonotone.—This equipment is available with either bone-conduction or air-conduction instruments, connected to double-jack boxes mounted beneath the arms of the seats in the auditorium. A separate amplifier, placed across the output of an RCA amplifier, or connected to a magnetic microphone hung in front of the loud speakers upon the stage, is employed.

RCA Trans-Lux.—Arrangements have been made with the Trans-Lux Daylight Picture Screen Corporation for marketing their patented device which provides for rear projection equipment in conjunction with RCA Photophone equipment.

OPTICAL REDUCTION SOUND PRINTER*

M. E. COLLINS**

A new machine for optically reducing sound prints from 35 to 16 mm., known as the *RCA PB141* optical reduction printer, is complete in itself with all parts mounted upon the main casting, which in turn is mounted upon a base and

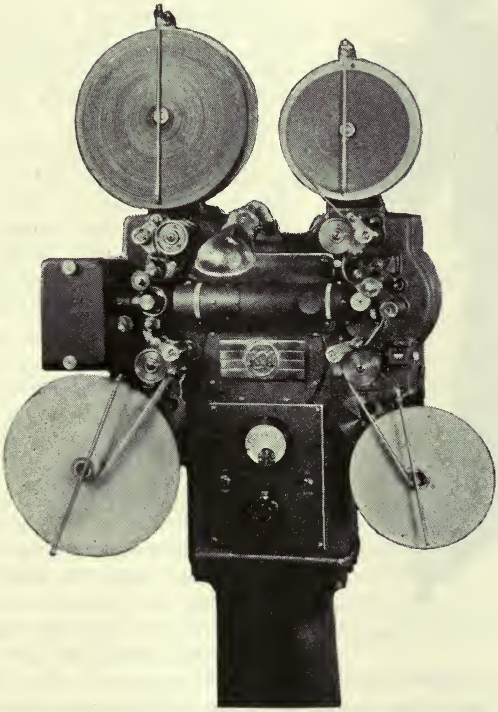

FIG. 1. RCA model *PB141* optical reduction printer.

pedestal equipped with casters so that the unit may easily be moved. The unit may be used in this form, or the base and pedestal may be removed and the printer mounted upon a table.

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* Presented at the Fall, 1935, Meeting at Washington, D. C.

** RCA Manufacturing Co., Camden, N. J.

As normally supplied, the printer operates on a 220-volt, 3-phase supply, 50 or 60 cycles. The printing lamp requires a low voltage (12 volts) d-c supply, which is not supplied as part of the printer.

An important feature of the machine is the use of a rotary stabilizer mechanism for moving both the 35-mm. and 16-mm. film at constant speed past the point where scanning and printing are accomplished. The drums over which the films pass do not subject the film to abrasion as would possibly occur with a film gate type of construction. The stabilizer drum units are in no way mechanically connected to the film sprockets or other gear-driven mechanisms, thereby avoiding reactions from those sources that might impair the quality of the printed sound-track.

FIG. 2. Rear view of printer.

On the left-hand side of the printer (Fig. 1) is located the 35-mm. film-propelling mechanism. The 16-mm. film-propelling mechanism is located at the right-hand side of the printer casting and is essentially the same as that used on the 35-mm. side.

The feed reels are located at the top and the take-up reels at the bottom of the printer casting. The films are threaded with the emulsions facing each other. Immediately to the left of the 35-mm. film-driving mechanism is located the optical system that focuses the scanning beam upon the negative being printed. The optical system used to reduce the track in the proper proportion in both the horizontal and the vertical planes is located between the two films and is in the same horizontal plane as the illuminating optics. All optical adjustments are completed and sealed at the factory. The control panel is located directly below the optical system.

The printer motor and the receptacle panel are mounted upon the back of the main casting (Fig. 2). The unit is intended to be operated in the darkroom, and is provided with a safety threading lamp. The back of the printer is completely enclosed, and all gears run in oil. A handwheel is provided at the back of the motor for testing the film motion before applying the power. A footage counter indicating 35-mm. feet is provided.

The optical system projects an image of a portion of the moving 35-mm. sound-track upon the surface of the 16-mm. film, which image moves in the same direction and exactly at the same speed as the 16-mm. film, so that no relative motion between the image and the 16-mm. film occurs. The 35-mm. track is illuminated by an aperture image, but this image is not narrow, as is the scanning slit used in reproducers. The scanning image is about 0.010 inch wide, and at a frequency of 10,000 cycles about 6 waves are imaged upon the 16-mm. film. The border

lines for either side of the sound-track of the 16-mm. film are produced by making the scanning mask for the 35-mm. sound-track longer than the standard 16-mm. track width. The edge of the scanning aperture adjacent to the picture frame is adjustable so as to compensate for any slight variation in location of the picture frame or picture frame lines that may have resulted when the 35-mm. sound print or negative was printed in a commercial 35-mm. printer. This permits blocking off such irregularities as might otherwise appear upon the 16-mm. sound print.

A sufficient range of illumination is provided so that satisfactory reductions can be made from both variable-width and variable-density records, whether negatives or positives. In general, the printer lends itself equally well to two types of reduction:

(*1*) 16-mm. prints directly from 35-mm. negatives or duplicate negative sound-tracks.

(*2*) 16-mm. duplicate negatives from 35-mm. positive sound-tracks.

Optically reduced 16-mm. sound-tracks are superior in quality to sound-tracks produced by processes involving contact printing. This is attributable, in variable-width work, to increased effective contrast of the negative; and, in both variable-width and variable-density work, to the absence of contact printing losses due to imperfect contact and slippage between negative and raw stock. Also, the printer is superior to those optical reduction printers that scan the 35-mm. film with a thin line of light without producing a printing image whose longitudinal magnification is equal to the ratio of the film speeds. In such printers, slit loss occurs similar to that occurring in recorders and reproducers. The *PB141* printer is free of such losses.

THYRATRON REACTOR THEATER LIGHTING CONTROL*

J. R. MANHEIMER**

The reasons for the use of electronic tube control of theater lighting have been discussed previously by the writer in a paper[1] describing a rectifier tube control employing reactances, such as was installed in the Center Theater at New York. The present paper deals with a type of board for accomplishing similar results in a slightly different manner, which was installed in the Metropolitan Opera House, also at New York.

The thyratron reactor equipment has several distinctive features. The first is automatic voltage regulation of each lighting circuit, to maintain a lamp voltage corresponding to the position of the intensity control. This makes it possible, without the series type of dimmer, to change the number and size of lamps on a particular circuit and yet maintain the same circuit voltage without readjusting the setting of the intensity control.

The second is the method of pre-setting and maintaining proportionate fading

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* Presented at the Fall, 1935, Meeting at Washington, D. C.

** E-J Electric Installation Co., New York, N. Y.

between pre-sets. The fader consists of a single unit which can be connected by means of the pre-set selector switch to supply excitation to any pair of pre-set master intensity controls, as shown in Fig. 1. A pre-set master, in turn, supplies the excitation to all voltage regulators in the individual control units associated with one pre-set. With the exception of a single switch having three positions located in each control unit, which disconnects the output of the voltage regulators and reconnects one of the voltage regulators to the rehearsal masters, there are no contacts between the individual unit and its associated tube panel. Some types of

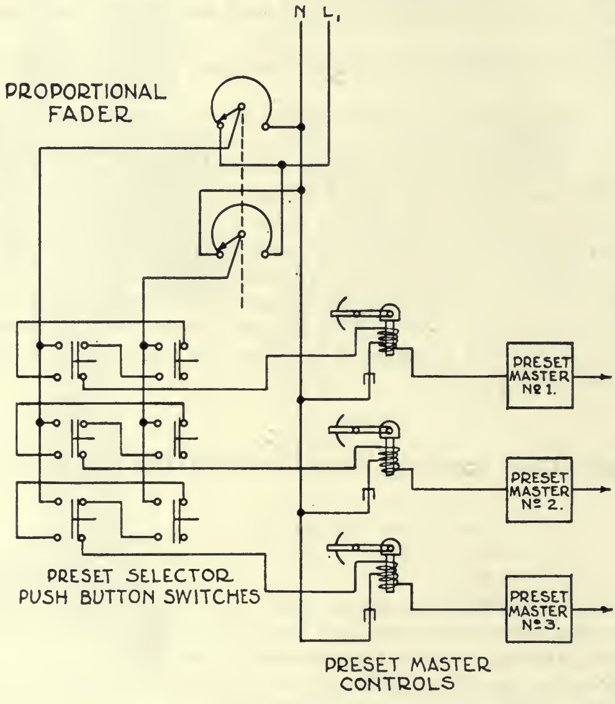

FIG. 1. Schematic diagram of proportional fader and preset masters.

tube-reactor control use individual fading devices for the separate circuits which are all mechanically connected together and driven simultaneously during the fading operation. Pre-set selector contacts are likewise duplicated for the individual fading devices, in addition to the selector switches described above. Further, sliding contacts are generally used in the intensity control unit.

Third, the speed of operation of the thyratron reactor system is extremely rapid, due partly to the absence of amplification between the intensity control and the tube unit supplying the direct current to the saturable reactor; and partly to the regulating characteristic of the tube unit, which applies overvoltage to the

saturable reactor until the voltage of the lighting circuit nearly corresponds to the voltage output of the voltage regulator intensity control. This forcing action, in connection with the saturable reactor, eliminates a large part of the sluggishness that has been associated with dimmers of the reactor type.

Fourth, the saturable reactors are constructed so that the windings are completely surrounded by iron. This is accomplished by using a four-legged core which shields the magnetic circuit from stray fields and the influence of neighboring magnetic materials. The windings are also protected from damage by this construction.

Referring to Fig. 2, the operation of the tube unit is as follows: The d-c. voltage

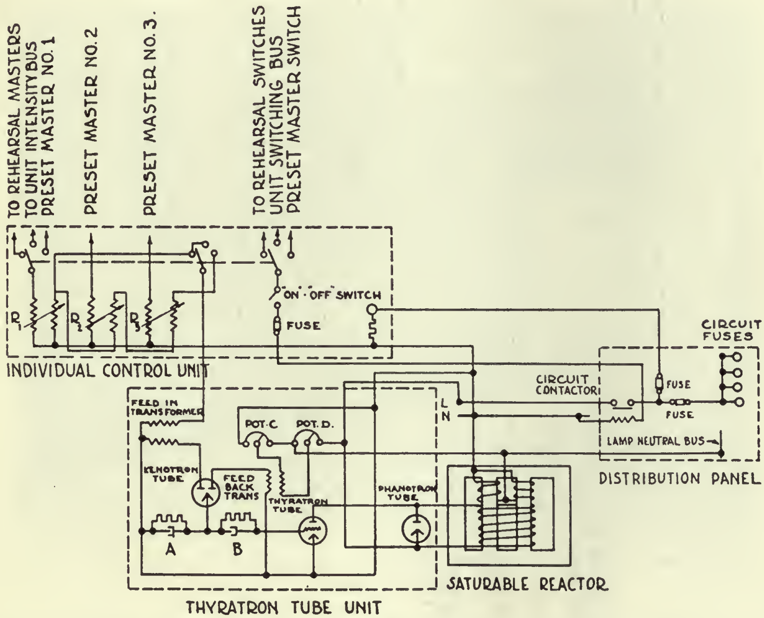

FIG. 2. Schematic diagram of thyratron reactor tube unit.

across the capacitor *A* is derived from the intensity control of the individual control unit and rectified by one of the two circuits of the full-wave kenotron. The other half of the kenotron rectifies the voltage of the lighting circuit, and the rectified voltage appears across capacitor *B*. Capacitors *A* and *B* are connected in series with the grid of the thyratron, the output of which supplies direct current to the saturable reactor. The voltage across capacitor *A* "turns on" the current, while the voltage across capacitor *B* "turns off" the current of the thyratron. The algebraic sum of these two voltages regulates the direct voltage supplied to the saturable reactor so as to maintain a lighting circuit voltage equal to the output voltage of the intensity control voltage regulator.

The phanatron is a half-wave rectifier, connected directly across the d-c. winding

of the saturable reactor to maintain the current constant in this winding during the negative half-cycle when the thyratron does not supply current.

Potentiometer C provides an adjustment of the lighting circuit voltage when the intensity control is set at zero, while potentiometer D provides a similar adjustment when the current is maximum. These adjustments are independent of each other, and need be made only when the equipment is installed, to compensate for variation in the impedance of the circuit wiring. The change in tube

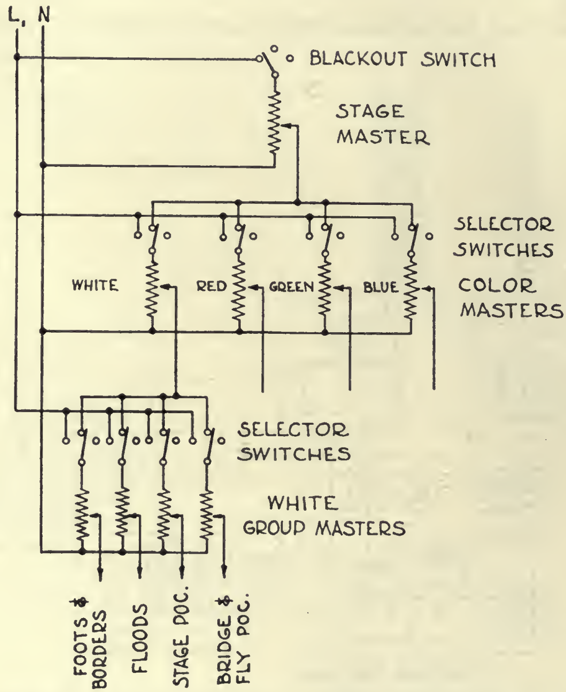

FIG. 3. Schematic diagram of stage rehearsal masters.

characteristic resulting from aging or high operating temperatures does not necessitate changing the settings of the potentiometers, since the regulating action of the tubes fully compensates for these variations.

The Metropolitan Opera House installation consists of two groups of apparatus—the pilot controller and the reactor group. The pilot controller, shown in Fig. 3, is arranged so that all stage and house individual control units, rehearsal group masters, and constant circuit switches are located on the main section. The stage and house masters, color masters, scene masters, faders, pre-set selector push-button, and blackout switches are all on the master section shown at the right-hand side of the controller. The master is so located that the operator, while controlling the lighting, can observe the stage through an opening in the stage

floor between the curtain and the footlights. The individual control in each horizontal row corresponds to circuits of separate color groups. The intensity control handles and switch handles are arranged in horizontal rows so that their relative positions can be readily seen.

The individual control unit consists of three voltage regulators, one for each of three pre-sets, corresponding operating handles with intensity scales, a three-position selector switch, an "on-off" switch, and an indicating light. The wiring connections to the individual control units are made up in flexible cables attached to plugs. Receptacles for these plugs are located in horizontal wiring troughs.

The saturable reactor has two a-c. windings, connected in parallel, on a four-

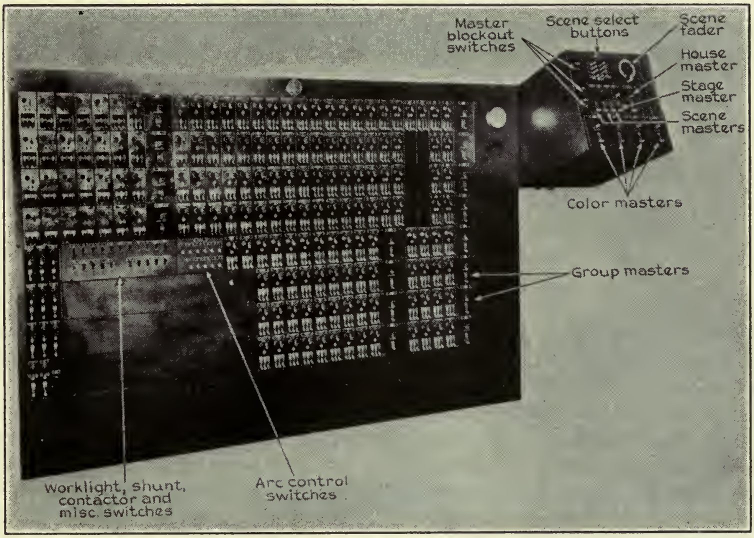

FIG. 4. Master controller for theater light intensity, with thyratron reactor power control.

legged core, and a d-c. winding around both the a-c. coils as indicated in Fig. 2. The a-c. flux circulates around the two center legs, and the d-c. flux passes from the center legs through the outside legs. The a-c. flux does not induce any voltage in the d-c. coil because it passes through the d-c. winding in both directions. Both the a-c. and the d-c. windings are around the same part of the magnetic circuit, which renders the d-c. flux very effective in saturating the reactor.

The closed circuit formed by the a-c. coils prevents the induction of any transient voltage in the d-c. winding, and eliminates the necessity of connecting a resistor across this winding to absorb transient energy.

The saturable reactor is so designed that, in combination with the tube unit, the dimming characteristic is maintained unchanged with a four to one change in load. In other words, if the connected load is reduced to 25 per cent of the reactor rating, the lighting intensity will still correspond to the setting of the intensity

control of the individual control unit. Saturable reactors are connected in the neutral of the circuit so that the lighting circuits are protected at all times in case of a ground.

Line booster transformers are installed to increase the voltage supply and to compensate for voltage drop in the reactor at full load. The voltage output of the booster transformer is 10 per cent of the normal line voltage, which limits the no-load voltage of each circuit to 110 per cent of normal line voltage. Due to the automatic regulation of each circuit, the maximum voltage for connected loads between 25 and 100 per cent of the reactor rating will not exceed the normal voltage.

REFERENCE

[1] MANHEIMER, J. R., AND JOSEPH, T. H.: "Electronic Tube Control for Theater Lighting," *J. Soc. Mot. Pict. Eng.*, **XXIV** (March, 1935), No. 3, p. 221.

FOTO FADE, A CHEMICAL AND DYE MIXTURE FOR POSITIVE FADES*

T. R. BARRABEE**

Since the beginning of the motion picture industry there has been a need for a simple process for making positive fades on film being edited. Such a dye mixture is available in Foto Fade which easily produces dye fades on positive film.

There has been constant research for this type of material, but without much success; but a material is now available which on test by most of the larger studios and laboratories in Hollywood appears to produce the desired result. The fade produced is quite neutral in color from the light to the dark end, and is more uniform in its change than the fade obtained by diaphragm manipulation in the camera.

Two hundred grams of Foto Fade is dissolved in twenty gallons of water, care being taken to assure complete solution of the dye in the chemical mixture. The dye solution may be kept practically indefinitely in deep wood, glass, or rubber tank. The film, weighted at the lower end, is slowly immersed frame by frame until the complete length desired is covered by the solution. The film should be rinsed before squeegeeing with damp chamois cloth before drying. The maximal density of dye is attained in about one minute.

Although the use of Foto Fade has been restricted mostly to the professional field up to the present, it is equally applicable to substandard films. Since few amateur cameras are equipped with variable shutter mechanisms, a material for the easy production of positive fades should be particularly interesting to the amateur.

---

* Received Nov. 11, 1935.

** Dye Research Laboratories, Los Angeles, Calif.

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HEADQUARTERS

The Headquarters of the Convention will be the Sagamore Hotel, where excellent accommodations are assured. A reception suite will be provided for the Ladies' Committee, who are now engaged in preparing an excellent program of entertainment for the ladies attending the Convention.

Special hotel rates guaranteed to S. M. P. E. delegates, European plan, will be as follows:

One person, room and bath....................	$ 3.50
Two persons, room and bath...................	6.00
Parlor suite and bath, for two.................	10.00
Parlor suite and bath, for three...............	12.00

Room reservation cards will be mailed to the membership of the Society in the near future and everyone who plans to attend the Convention should return his card to the Hotel promptly in order to be assured of satisfactory accommodations. Registrations will be made in the order in which the cards are received. When the Sagamore Hotel is booked to capacity, additional accommodations will be provided by the Hotel Arrangements Committee at another hotel in the immediate vicinity of the Sagamore.

A special rate of fifty cents a day has been arranged for S. M. P. E. delegates who motor to the Convention, at the Ramp Garage, near the Hotel.

TECHNICAL SESSIONS

An attractive program of technical papers and presentations is being arranged by the Papers Committee. Sessions and entertainment programs will be conducted at the Sagamore Hotel and at the plants of the Eastman Kodak Co. and the Bausch & Lomb Optical Co. in accordance with the tentative program which follows.

The attention of authors is directed to an announcement of the Papers Committee at the bottom of the inside cover of this issue of the JOURNAL. Those

who contemplate submitting manuscripts for the Convention should communicate with the Papers Committee as promptly as possible.

SEMI-ANNUAL BANQUET

The Semi-Annual Banquet and Dance of the Society will be held at the Oak Hill Country Club on Wednesday, October 14th, at 7:30 P.M. Motor-coach transportation will be provided to and from the Club by the Transportation Committee.

INSPECTION TRIPS

Arrangements will be made on the days when the sessions are conducted at the plants of the Eastman Kodak Co. and the Bausch & Lomb Optical Co. to make tours of inspection of the plants. The members of the Society are also invited to be the guests of those companies at luncheon on those days.

PROGRAM

Monday, October 12th

9:00 a. m.	*Sagamore Hotel Roof* Registration Society business
10:00 a. m.–12:00 p. m.	Committee reports Technical papers program
12:30 p. m.	*Sagamore Hotel Main Dining Room* Informal Get-Together Luncheon for members, their families, and guests. Brief addresses by several prominent members of the industry.
2:00 p. m.–5:00 p. m.	*Sagamore Hotel Roof* Technical papers program.
8:00 p. m.	*Eastman Theater* "Color Photography" (with demonstrations and motion pictures), Dr. C. E. K. Mees, *Vice-President in Charge of Research,* Eastman Kodak Co., Rochester, N. Y.

Tuesday, October 13th

The Convention will be in technical session on this day at the plant of the Eastman Kodak Co., at Kodak Park. Delegates will be the guests of the Eastman Kodak Co. at luncheon, and provision will be made for making a tour of inspection of the plant.

The program for the evening of this day will be announced in a later issue of the JOURNAL.

Wednesday, October 14th

The Convention will be in technical session on this day at the plant of the Bausch & Lomb Optical Co. Delegates will be the guests of the Bausch & Lomb Optical Co. at luncheon, and provision will be made for making a tour of inspection of the plant.

7:30 p. m. *Oak Hill Country Club*

Semi-Annual Banquet and Dance of the S. M. P. E.: addresses and entertainment. Motor-coach transportation will be provided to and from the Club by the Transportation Committee. Coaches will leave the Hotel promptly at 7:00 P.M.

Thursday, October 15th

10:00 a. m.–12:00 p. m. *Sagamore Hotel Roof*

Technical papers program

2:00 p. m.

Technical papers program
Society business
Adjournment of Convention

SOCIETY ANNOUNCEMENTS

STANDARDS COMMITTEE

At a meeting of the Standards Committee held on June 11th at the Hotel Pennsylvania, New York, N. Y., new drafts of the drawings for the revised issue of the Standards Booklet were carefully considered by the Committee, and the complete revision will probably be ready for the final action of the Committee within a few weeks. As announced previously, no change is being made in the content of the drawings, but an effort is being made to present the material in a more lucid and practicable fashion.

PROJECTION PRACTICE COMMITTEE

The last regular monthly meeting of the Committee was held on June 18th at the Paramount Building, New York, N. Y., at which plans to be followed by the Committee in the fall were discussed. Particular attention is being paid to the question of screen brightness and theater illumination, in collaboration with the Projection Screen Brightness Committee whose reports appeared in the May, 1936, issue of the JOURNAL. A study is being made also of the various state and municipal ordinances pertaining to motion picture projection, with the idea in view of paving the way toward greater uniformity in these regulations in the future.

PACIFIC COAST SECTION

On May 26th a joint meeting of the Pacific Coast Section of the S. M. P. E. and the Technicians Branch of the Academy of Motion Picture Arts and Sciences was held at the Metro-Goldwyn-Mayer Studios, at Culver City, Calif.

Approximately 400 persons attended the meeting. Mr. Gerald Rackett, Chairman of the Pacific Coast Section, acted as chairman of the meeting, introducing Mr. Douglas Shearer, Sound Director of Metro-Goldwyn-Mayer Studios, who conducted the symposium on "Essential Improvements Achieved in Sound-Film Recording and Reproduction in Adapting Conventional Methods to the High-Quality Requirements of Motion Pictures."

During the symposium Mr. Shearer discussed the following subjects, illustrating some of them by means of lantern slides or recordings:

"Push-pull" recording and reproduction as a means of attaining increased volume range and minimum distortion. Variable-width and variable-density methods and Class *A* and Class *B* systems. Adaptation to stereophonic reproduction.

Side matting of sound-tracks; manual and automatic.

Biasing methods; high-speed, carrier type, split-frequency, light-biasing.

Valve ribbon travel frequency intermodulation.

Ultraviolet and monochromatic recording.

Light-valve development and design.

Halation studies.

Complete re-recording of all release product as standard practice, and the choice of methods and standards for studio recording.

Improved sound printer developments.

Development of improved apparatus for moving sound-film without speed variation or flutter.

The general reproduction problem in the theater.

The Shearer two-way horn system.

Amplifier requirements.

Optimal reproducing scanning-slit width.

Screens.

The M-G-M automatic control system for production units.

A new type of recording microdensitometer.

In view of the fact that the meeting ran so late into the evening that there was no opportunity for discussion, an additional meeting was arranged for the evening of Tuesday, June 2nd, also at the Metro-Goldwyn-Mayer Studios. At this meeting Mr. Homer G. Tasker, President of the S. M. P. E., acted as Chairman. About 150 persons attended and a very lively and interesting discussion ensued based upon many of the subjects covered by Mr. Shearer at the previous meeting.

SOCIETY SUPPLIES

The following are available from the General Office of the Society, at the prices noted. Orders should be accompanied by remittances.

Aims and Accomplishments.—An index of the *Transactions* from October, 1916, to December, 1929, containing summaries of all articles, and author and classified indexes. One dollar each.

Journal Index.—An index of the JOURNAL from January, 1930, to December, 1935, containing author and classified indexes. One dollar each.

SMPE Standards.—Reprints of *SMPE Standards and Recommended Practice.* Twenty-five cents each.

Membership Certificates.—Engrossed, for framing, containing member's name, grade of membership, and date of admission. One dollar each.

Lapel Buttons.—The insignia of the Society, gold filled, with safety screw back. One dollar each.

Journal Binders.—Black fabrikoid binders, lettered in gold, holding a year's issue of the JOURNAL. One dollar each. Member's name and the volume number lettered in gold upon the backbone at an additional charge of fifty cents each.

JOURNAL

OF THE SOCIETY OF

MOTION PICTURE ENGINEERS

Volume XXVII **AUGUST, 1936** **Number 2**

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JOURNAL
OF THE SOCIETY OF
MOTION PICTURE ENGINEERS

SYLVAN HARRIS, EDITOR

Subscription to non-members, $8.00 per annum; to members, $5.00 per annum, included in their annual membership dues; single copies, $1.00. A discount on subscriptions or single copies of 15 per cent is allowed to accredited agencies. Order from the Society of Motion Picture Engineers, Inc., 20th and Northampton Sts., Easton, Pa., or Hotel Pennsylvania, New York, N. Y.

Published monthly at Easton, Pa., by the Society of Motion Picture Engineers.
Publication Office, 20th & Northampton Sts., Easton, Pa.
General and Editorial Office, Hotel Pennsylvania, New York, N. Y.
Entered as second class matter January 15, 1930, at the Post Office at Easton, Pa., under the Act of March 3, 1879.

See p. 228 for Technical Committees

REPORT OF THE PROJECTION SCREEN BRIGHTNESS COMMITTEE*

In the May, 1936, issue of the JOURNAL there appeared a group of papers that set forth practically all the extant knowledge concerning the problem before this Committee. A brief résumé of the state of our work is now in order. We, as a committee, are now in a position to evaluate the data at hand and to discuss the need for future work. In this report reference to the May issue will be made by page number for the benefit of the reader who wishes to inspect the evidence upon which any of our statements are based. The things we know are:

The fundamental data of physiological optics are of questionable application to the screen brightness problem, because no work has ever been reported in which conditions existing in motion picture projection are duplicated (*Lowry, p. 490*). The very complete bibliography of this paper (*p. 500*) is recommended to those wishing to study the data of visual functions. It is of interest to note that the data of visual acuity indicate definitely that all the detail customarily resolved by the motion picture process is visible under what common sense and common experience tells us is a brightness much too low for visual comfort (*Lowry discussion, p. 518*). Since acuity is not a useful criterion of minimal screen brightness, other types of psychophysical tests are required.

Of such tests we have some information in the paper by Luckiesh and Moss (*p. 578*), in the experiments reported by Wolf (*p. 538*), and in the experiment of O'Brien and Tuttle (*p. 505*). This latter experiment gives rather strong evidence of the desirability of a high brightness level—about 30 foot-lamberts, as measured at the center of the screen with the projector running and with no film in the gate. Somewhat contrarily to expectation, the brightness level of screen surroundings does not affect the selected picture brightness in any considerable degree, but there is a marked preference for a surrounding brightness greater than zero—actually, about 0.05 foot-lambert is

* Presented at the Spring, 1936, Meeting at Chicago, Ill.

preferred. This finding may be regarded as an important empirical contribution to the little-known subject of "glare" and its avoidance. The data of O'Brien and Tuttle indicate that a tolerance in the screen brightness of about ±50 per cent would be reasonable. This tolerance is based upon individual observer variation and scene subject variation.

The general conclusions of this empirical work are substantiated by the discussion offered by Luckiesh and Moss (*p. 578*) in which viewing motion pictures is compared to other visual tasks concerning which a greater mass of data is available. Some of the data quoted by Wolf (*p. 538*) place the desirable level somewhat lower.

It is the desire of the Committee to adopt a critical attitude toward the work that has been quoted; not to cast doubt upon the results of the careful work of these authors, but rather to stimulate the repetition of similar experiments by others. The importance of the subject certainly justifies the expenditure of time by able investigators in the realm of physiological optics.

In the case of the O'Brien-Tuttle investigation, the possible weaknesses as pointed out by the authors are:

(*1*) Actual theater conditions are not exactly duplicated.

(*2*) Release print quality may not be represented accurately.

(*3*) It is only inferred, not proved, that the brightness values selected by the observers are best from the point of view of avoidance of fatigue. Pending the completion of other work along similar lines, the Committee is inclined to accept the conclusions that the brightness level should be something of the order of 30 foot-lamberts, and that a peripheral brightness of the order of 0.05 foot-lambert is desirable at this brightness level. If such a brightness were attainable, logical brightness limits would be 20 foot-lamberts minimal and 45 foot-lamberts maximal.

O'Brien and Tuttle have made the suggestion (*p. 516*) that the classical Weber-Fechner law may be applied to the problem. The argument presented, based upon the correlation of screen brightness of the highlight area with desired contrast, is one that should be followed up.

We may now inquire regarding the factors not dealt with by these investigators that may affect the desired brightness level as determined for the empty-running projector. In this connection, we have to consider only two factors, the human eyes and the release print densities.

There are not enough data on the effect of screen size (or subtended angle) on the influence of color of the reflected light, or on the influence of auditorium illumination upon visual adaptation. Work along these lines should be encouraged by the Committee, although we can state that the magnitude of these effects is probably small.

The possible effects of release print density we can evaluate more definitely. We ask, can the required brightness be lessened by making prints lighter? Would there be any improvement in picture quality if release prints were made denser? This procedure would require a brightness level even higher than that found by O'Brien and Tuttle for typical modern release prints.

To the first question we can answer "no." Average release prints are being made as transparent as possible with existing photographic materials. Lighter printing would endanger tone reproduction in the highlight region (*Tuttle, p. 553*).

To the second question we may answer "yes, but only by a slight amount." An increase of about 0.15 in the density of all release prints would place the highlight density of release prints on or near the straight-line portion of the positive characteristic in almost every case, and would probably improve tone reproduction. Supposedly, the required brightness would have to be increased about 40 per cent to afford optimal viewing conditions.

The next point to consider is what screen brightness is possible. For that purpose we turn to the data of Cook (*p. 530*), who gives us the maximal brightness values attainable theoretically with apparatus and sources with their present practical limitations. As an example, we may draw upon his data to compute the conditions appertaining to a large screen with the best of modern projection equipment. We may assume for this purpose a 13.6-mm., high-intensity arc, a 5-inch $f/2.4$ lens, and a diffuse reflecting* screen 25 feet wide. The data in Table I are pertinent:

TABLE I

Lumens Available	5000
Lumens Reflected	3750 (75% reflection assumed)
Screen Area	469 square-feet
Average Brightness	8 foot-lamberts

* It is probable that only a diffuse screen would be satisfactory in any theater that would require a wide screen. Directional screens are of advantage only in narrow theaters. A directional wide screen will detract seriously from the brightness uniformity from side to side, especially for those seated to the side of the screen.

No projector optical system is capable of delivering uniform illumination. With a good system well adjusted, the distribution of brightness would be as given in Table II, for the stations indicated in Fig. 1. No more uniform values than these can be expected under actual operating conditions.

TABLE II

Station	Brightness *Foot-Lamberts*
1	9.6
2	9.2
3	8.1
4	6.2

As a rough approximation Table III shows the maximal brightness attainable with screens of different widths. The values apply to the center of the field, and again are based upon the best commercial optical systems in perfect adjustment.

TABLE III

Screen Width *Feet*	Center Brightness, Projector Empty *Foot-Lamberts*
30	6.7
25	9.6
20	15.0
15	27.0

These values represent optimal conditions, which are probably seldom fulfilled in practice. Reported greater central brightness for the given screen size is usually attained only at the sacrifice of overall uniformity.

Data given by Wolf for recent brightness measurements in theaters (*p. 539*) are not far out of line with these theoretical values, which fact shows that the projectionists, in general, are probably doing a good job.

Now, the discrepancy between the desired value of 30 foot-lamberts and the maximum attainable with large screens will probably present a serious stumbling block in the way of standardization. An art or science in its progress toward perfection will, of course, resist an attempt to standardize if the standard has to be set at anything less than perfection. Since the beginning of the motion picture, when the optical system of the projector was a modified magic lantern and the

source was the lime light, there has been steady progress in the struggle to supply more light. An attempt was once made to standardize at a brightness of the order of 2 foot-lamberts* (*Wolf, p. 537*). Such a recommendation, while it probably did little harm, certainly was of no value to the industry. What then are the possible virtues of standardization at the present time?

The interest that has been shown in the activities of this Committee, both inside and outside the Society, is good evidence of the general

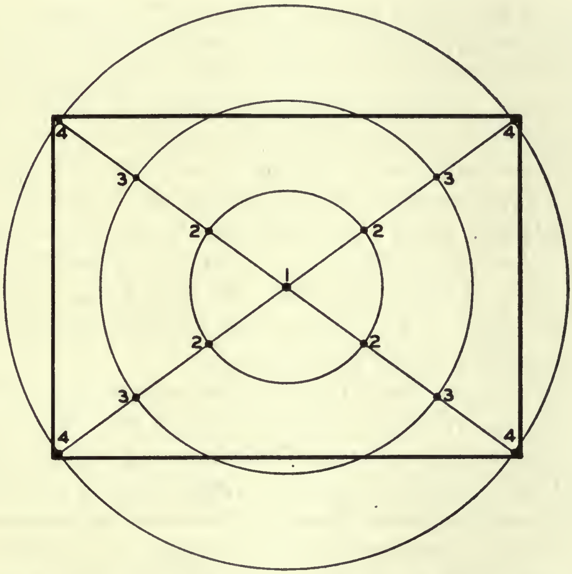

FIG. 1. Stations for which brightness values have been computed.

belief that there is room for improvement. We have heard comments upon all sides to the effect that a film that looks fine in one theater is very poor in another. Statements by Leshing (*discussion, p. 543*[3]) are very enlightening. Something is wrong if a picture printed in Hollywood is entirely satisfactory when reviewed there, but "was so bad as to be almost unrecognizable" when projected in another

* Since the "recommended" value was "2.3 foot-candles on the screen," with none of the necessary conditions such as shutter or screen surface specified, the value of brightness may merely be inferred.

theater. It is logical to hope that brightness standardization would remedy this situation.

It appears to the Committee that the decision of whether or not to attempt standardization depends both upon the *rate* of improvement of projection optics and the possible *rate* at which improvements and inventions can be adopted by the theaters. Improvements in optics and projection sources are certain to take place, but it seems highly improbable that the available brightness will be doubled or tripled within the next few years. It will require time merely to bring existing theaters up to date in the matter of projection equipment, and no one can predict how rapidly improvements will be accepted in the future. We propose then to discuss a standard that must be regarded as temporary, because, for practical reasons, it must fall short of the ideal.

For a standard admittedly based upon expediency, we are definitely committed to a value that is at least theoretically achievable by the majority of large theaters. We suggest the 30-ft. screen* as an arbitrary limiting size, which the Society should attempt to bring within the pale of its recommendation. This sets the minimal brightness, in round numbers, at 7 foot-lamberts. We intend that this value shall refer to the center of the screen, and shall be measured with the projector running without film in the gate.

Regarding an upper limit, there are two courses open. Recognizing the fact that our recommended minimum is far below the ideal, it might be logical to place the ideal of 30 as a top value. This procedure might not be satisfactory, for it might not lead toward sufficient uniformity from theater to theater. The second alternative is to set the top level at a value such that the quality of a release print adjusted for projection at the mean level will not suffer if projected at either of the extremes.

The experimental data needed by the Committee to fix a logical upper limit upon this basis will not be available for some time. This point will be mentioned again in connection with the future plans of the Committee. Briefly, the problem is to determine the brightness range throughout which the appearance of the picture is not materially altered by the brightness level.

Application of the existing data relating to the Fechner fraction and brightness is a questionable procedure. Data of this nature have been

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* The Committee lacks certain statistical data regarding screen sizes in the United States. Also some data relating viewing distance with *required* screen size are pertinent.

determined under restricted experimental conditions for photometric fields, and a somewhat different relationship between field brightness and contrast sensitivity may eventually be found for the viewing conditions of motion picture projection.

Nevertheless, although the conclusions may not be entirely convincing, it seems fruitful to make use of this material in an attempt to evaluate the effect of screen brightness upon picture contrast. From the data of Blanchard[1] we have constructed the curve shown in Fig. 2. This curve shows, for the brightness region in which we are

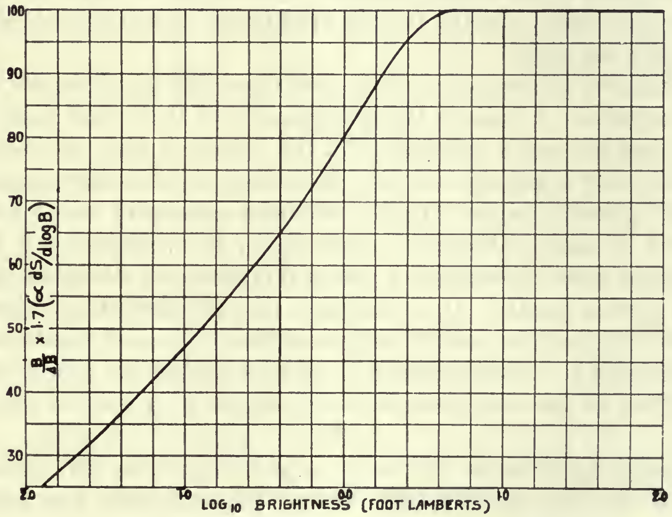

FIG. 2. Curve relating the Fechner fraction with field brightness.

interested, the first derivative of the sensation/brightness relation as a function of log brightness. The ordinates have been adjusted to read in per cent of the maximal slope. In words, this curve gives us the value of the visual effect of the image brightness upon contrast. If we assume the Blanchard data to hold for the conditions of motion picture projection, we have a quantitative evaluation of the psychological factor which, when multiplied by the physical factor $dD/d \log E$ for the positive reproduction, will give us a new gradient applying to the appearance of the screen image at any level of brightness.

In Table IV we have taken a series of values for empty-projector screen brightness and have computed from Tuttle's average release

print data (*p. 551*) the brightness of various portions of the screen picture. In columns adjacent to the picture brightness values are given the value of slope taken from Fig. 2. These figures evaluate directly the subjective contrast effect. If, for instance, one looks only at the highlight of a picture, the subjective contrast is almost equal to the physical contrast, and changes only about three per cent as the empty projector-screen brightness is varied between 7 and 30 foot-lamberts. If one looks at the shadow, the apparent gamma is changed by about 50 per cent in passing from 7 to 30. If one is impressed by the brightness of the area of principal interest, the factorial variation is thirty per cent. For the average brightness, the variation is about thirty-five per cent.

We have no entirely convincing data regarding the allowable contrast variation. Certainly the discrepancies of individual taste will allow some tolerance. Indicative of the deviation from the selected contrast that is permissible, we may refer to laboratory practice in making release prints. Here a gamma variation of ten to fifteen per cent is usually allowed.[2] Presumably, this tolerance has been established upon the basis of a practical criterion of allowable variation in picture quality. It is reasonable that the allowable subjective contrast effect of the screen brightness level tolerance should be of the same order. In other words, a picture should not appear more than 10 or 15 per cent more contrasty at the high than at the low level.

Referring again to the derivative curve in Fig. 2, we find by interpolation that for the highlight region, the maximum can not be high enough to affect contrast by as much as 15 per cent.

For the shadow region, the subjective contrast varies so rapidly that if we formed our judgment upon this part of the picture, we should be able to allow scarcely any tolerance in screen brightness. It is probable, however, that the shadow area has very little significance in the evaluation of the picture contrast, since the extreme shadow region probably appears entirely black regardless of the screen brightness level (*Lowry, p. 493*).

Either of the other two values—that of the average brightness or the brightness of the area of principal interest, is probably a good criterion upon which to base our subjective contrast tolerance. Referring to these values, we find that the contrast increase amounts to about 7 per cent at 10 foot-lamberts and 15 per cent at 14 foot-lamberts.

TABLE IV

Effect upon Visual Contrast of Various Screen Brightnesses for Various Parts of the Average Picture

Empty Projector Brightness (*ft-lamberts*)	High-light Brightness ($D = 0.43$)	Contrast Seeing Ability $\frac{dS}{d \text{ Log } E}$	Shadow Brightness ($D = 2.40$)	Contrast Seeing Ability $\frac{dS}{d \text{ Log } E}$	Brightness Principal Interest ($D = 1.0$)	Contrast Seeing Ability $\frac{dS}{d \text{ Log } E}$	Average Brightness ($D = 1.15$)	Contrast Seeing Ability $\frac{dS}{d \text{ Log } E}$
7	2.7	0.97	0.028	0.33	0.7	0.75	0.5	0.69
10	3.7	0.99	0.040	0.37	1.0	0.80	0.71	0.74
14	5.2	1.00	0.056	0.41	1.4	0.87	1.00	0.80
18	6.7	1.00	0.072	0.44	1.8	0.92	1.28	0.85
22	8.1	1.00	0.088	0.46	2.2	0.94	1.56	0.88
26	9.6	1.00	0.104	0.48	2.6	0.96	1.85	0.92
30	11.1	1.00	0.120	0.50	3.0	0.98	2.13	0.94

CONCLUSION

It appears to the Committee, in view of the arguments that have been presented, that the industry might stand to benefit by the adoption of a temporary screen brightness standard. Logical limits for such a standard would appear to be 7 foot-lamberts for the low value and 14 for the high value.*

To recapitulate: The value *7* is based upon the value attainable for a diffusing screen about thirty feet wide with an efficient optical system in good adjustment. The value *14* is the limiting value beyond which print contrast adjusted for the mean level of 10 foot-lamberts will appear too great. The values should be determined at the center of the screen with the projector running with no film in the gate.

Even if the Standards Committee and the Society as a whole act favorably upon our suggested temporary standard, the Projection Screen Brightness Committee regards its work as far from complete. We list below a few of the many problems that confront us. Some of these things we can work upon as a Committee; some call for long and painstaking research by qualified experts, results of which can best be given in the form of Convention papers. Some call definitely for the coöperative efforts of other Committees, especially the Projection Practice Committee and the Laboratory Practice Committee.

* This suggestion, if adopted, would set a logical standard for laboratory screening room practice. A mean value of about 10 foot-lamberts should be adopted, and tolerance in this value should be made as small as is compatible with practical limitations.

We hope we shall earn the gratitude of future Papers Committees by listing these subjects for Convention papers. We hereby make an appeal for authors to undertake contributions designed to answer these questions:

(*1*) What correlation is there between best print contrast and screen brightness?

(*2*) What effect does the brightness standard have upon the standard of release print quality? Shall release prints of different contrasts be made available to theaters operating at different screen brightness levels? (Any work done on the standard release print must, for obvious reasons, consider the screen brightness standard if it is adopted.)

(*3*) Is highlight density, average density, shadow density, density of the area of principal interest, or a combination of these factors the thing that determines preferred brightness?

(*4*) What possibilities are there for improvement in projection optics, pull-down efficiency, and source brilliance?

(*5*) What is the effect of color of the light-source, color of the screen, and color of the print upon the desired brightness?

(*6*) What proportion of moving picture goers see pictures on screens greater than 20 feet, 25 feet, 30 feet? Statistical data on theater sizes, screen sizes, projection equipment, and attendance figures are needed by the Committee. A complete paper of this kind would be valuable also in connection with other problems confronting the Society.

(*7*) What factors determine screen width? Would it not be better, for instance, to use a 25-ft. screen at 9 foot-lamberts than a 30-ft. screen at 7 foot-lamberts? The data of visual acuity tell us that the picture detail visible at great viewing distances should not suffer.

(*8*) What are the possibilities for the development of simple, rugged, and inexpensive brightness-measuring instruments? Can not a satisfactory simple brightness tester be developed with two fields, one at the higher and one at the lower brightness limit? Could not such an instrument be used easily by the theater projectionist to determine whether he is operating within the recommended brightness range?

(*9*) What is the effect of auditorium illumination upon the required brightness level?

(*10*) What is the effect of the visual angle or the screen size upon this value?

(*11*) What tolerance in non-uniformity of screen brightness from center to edge should be established?

C. TUTTLE, *Chairman*

A. A. COOK
A. C. DOWNES
D. E. HYNDMAN
W. F. LITTLE
O. E. MILLER
G. F. RACKETT
H. RUBIN
B. SCHLANGER
A. T. WILLIAMS
A. K. WOLF

REFERENCES

[1] BLANCHARD, J.: "The Brightness Sensibility of the Retina," *Phys. Rev.*, **XI** (Feb., 1918), No. 2, p. 81. *Note:* Data by König, and Brodhun and Aubert have been found to be in good agreement with those of Blanchard.

(See TROLAND, L. T.: "The Principles of Psychophysiology" (Vol. II), *D. Van Nostrand Co.* (1930), New York, p. 77.)

[2] Bulletin, *Acad. Mot. Pict. Arts & Sci.*, July 27, 1935.

[3] Joint discussion of "A Review of Projector and Screen Characteristics, and Their Effects upon Screen Brightness," by A. A. Cook, and "An Analysis of Theater and Screen Illumination Data," by S. K. Wolf, *J. Soc. Mot. Pict. Eng.*, **XXVI** (May, 1936), No. 5, p. 543.

[4] LITTLE, W. F., AND WILLIAMS, A. T.: "Résumé of Methods of Determining Screen Brightness and Reflectance," *J. Soc. Mot. Pict. Eng.*, **XXVI** (May, 1936), No. 5, p. 570.

DISCUSSION

MR. CARLSON: I am somewhat concerned about the possible interpretation of a recommended level of screen brightness dictated by the limitation of present lighting equipment rather than the dictates of good practice. It would seem that a technical committee inquiring into a matter of this sort would be concerned with what it believed to be best, and would set up its conclusion as an objective toward which industry, projector manufacturers, and others might strive.

MEMBER: Will Mr. Tuttle please explain the translation from foot-lamberts to foot-candles?

MR. TUTTLE: Answering Mr. Carlson's objection first; we have, of course, considered the possibility of making our recommendation upon the basis of what is best. But to recommend the impossible would be no real benefit to the industry. Those who attended the last Convention heard a very convincing discussion by Mr. Leshing that showed that a disadvantageous situation exists in the theaters today that should be remedied. As we can not remedy it in the best way possible, it seems to us that there should be a partial remedy, in the form of a temporary recommendation. In our report we emphasize the fact that it is a temporary recommendation, which we wish to see changed in the future.

Answering the second question: the *foot-candle* is a unit of illumination, and is concerned with the quantity of light *striking* a surface. The *foot-lambert* is a unit of brightness, and is concerned with the quantity of light *leaving* a surface in a given direction. If a perfectly reflecting and perfectly diffusing surface were illuminated to an intensity of 1 foot-candle, it would have a brightness of 1 foot-

lambert. Illumination values given in foot-candles, then, can be converted to brightness values (foot-lamberts) by multiplying the illumination by the reflection factor of the surface. The factor would be about 75 per cent for a good diffusing screen.

MEMBER: Has the Committee obtained any data as to the over-all variation of screens throughout the country?

MR. TUTTLE: We have a great deal of that sort of data, obtained from various sources, but we do not know how reliable it is. Brightness measurements are made in so many different ways, and often the conditions under which the measurements are made are not specified. We do not know whether the projector was running or not; we do not know in what region of the screen the brightness measurements were made; we do not know what kind of instrument was used. There is a great lack of reliable data of this kind. An answer to your question would therefore be more or less a guess. I should say that the brightness varies probably between 2 and 25, in various theaters.

MEMBER: In your opinion the over-all variation is excessive?

MR. TUTTLE: I believe it is much in excess of what should be allowed.

MR. TASKER: The Committee in its report recommends or specifies some more or less standard method of measurement that may be used in the theaters?

MR. TUTTLE: Yes. We are making a recommendation, through one of the symposium papers,[4] although more work must be done on the subject. It would be very fine if we could have some new brightness-measuring instruments especially designed for the purpose.

MR. JOY: Were the values given by Mr. Tuttle average values over the whole screen, or merely the values at the center of the screen? If they were the average values, what consideration has been given to the distribution of the light upon the screen?

MR. TUTTLE: The values quoted were for the screen center. Distribution has been considered, but perhaps not at sufficient length. We have shown in Fig. 1 what we believe to be very good distribution.

MR. CARLSON: In that connection, would it not be better to define acceptable brightness uniformity in terms of rate of change of brightness, or brightness gradients—rather than in terms of an over-all change such as from the center to the corners.

MR. JONES: Is not that what was done? The values are given at various points; that determines the gradient.

We realize, of course, that it is undesirable to fix a standard below what we believe to be the most desirable. However, we have the situation that identical release prints are going out all over the country, some of which are shown in theaters having screen brightnesses of 2 foot-lamberts and some having perhaps 25. That is a very undesirable condition. If we can not realize the ideal screen brightness, we shall be much better off at least to limit the range over which the brightness varies, and so cure this difficulty of a print's looking all right in one theater and very bad in another.

We have to deal with a present situation, and can not wait several years until we get these screen brightnesses up to 30 or 40 foot-lamberts. We shall have to wait quite a while for that. In the meantime, we should do something to remedy a condition that now exists.

MR. GREENE: The theaters that would be most likely to have brightnesses below the 2 foot-lamberts mentioned would have so many other great and glaring faults that I believe they could be totally eliminated from consideration, particularly in a case of temporary standards.

MR. JONES: I do not believe that is quite true. In some of the finest theaters having excellent equipment, with screens 35 feet wide, these relatively low levels of screen brightness are found.

MEMBER: Within the past month a survey of theaters in Los Angeles showed that three theaters, in a group, had intensities of 5 to 22 foot-candles, and all three were called *de luxe* houses.

MR. TASKER: It has been stated that 5 foot-lamberts is the brightness of the Radio City Music Hall screen.

MR. DEPUE: When news weeklies are shown at the Roxy they are nearly twice the size of the feature picture. Can anyone tell what is the actual size?

MEMBER: I believe 44 feet.

MR. JONES: Is it possible with that type of print to produce news release prints that might be somewhat more transparent than a standard release print?

MEMBER: Not generally, because the release prints are made for use throughout the whole country, and the gamma and density of the prints are held closely to the values in production release prints.

MR. BRENKERT: In the Hollywood theaters mentioned, were the screens all approximately the same size? Was the same type of light-source used in taking the pictures? Was the brightness calculated without projecting a picture?

MEMBER: I did not take the pictures personally. The screens, I understand, were about the same size, with a very appreciable difference in the lengths of the throws. The house with the low brightness had a throw, I suppose, of about 50 or 60 feet.

MR. BRENKERT: It is important whether the light-sources were approximately, or anywhere nearly, the same—the projection distances were so different.

REPORT OF THE PROJECTION PRACTICE COMMITTEE*

The Committee has embarked upon what is probably its most important undertaking to date—the establishment of standards for the installation and operation of visual and sound projection equipment. When this work is complete, and considered in connection with the standard projection room lay-outs already published by this Committee, there will be available to the industry a valuable reference source covering the entire projection process.

Heretofore, the design, installation, and operation of projection equipment have been seriously hampered by a multiplicity of varying local and state regulations, a majority of which are undoubtedly well intentioned but which sometimes reflect a regrettable lack of knowledge of the projection process on the part of their sponsors. This situation operates to defeat the best efforts of manufacturers, exhibitors, and projectionists to attain better projection results; and also permits the rather widespread use of decidedly inferior equipment and encourages sub-standard installation and operating practices.

It is a not uncommon experience, for example, for a manufacturer to gain approval of his product in one state, whereas an adjoining state withholds approval and enforces changes in design that occasion unnecessary expense and impaired operating efficiency. Indeed, there very often exists a sharp distinction between state regulations and those promulgated by municipalities therein. Exhibitors are confronted with the same difficulties, and equipment having the approval of one city is often unacceptable to another city in the same state. Members of the Committee who have had long experience in practical projection work are agreed that the absence, rather than the existence of specific regulations in many states is highly undesirable, because the conditions to be met in such territories frequently lie within the province of some local official whose personal opinions are not consistent with generally approved procedure. There may then develop friction between the authorities of a given municipality

* Presented at the Spring, 1936, Meeting at Chicago, Ill.

wherein one division of the city government disagrees emphatically with another.

The Committee has set for itself the task of establishing projection standards which, it is hoped, will be acceptable not only to the Society but also to the nationally recognized regulatory boards. This goal having been attained, such standards could be submitted to the Sectional Committee on Motion Pictures, of the American Standards Association. Should complete success crown the efforts of the Committee in this direction there still would be lacking means of assuring their adoption by the various states, cities, and towns. It is assumed, however, that the prestige and authority accruing to the standards through the approval of the aforementioned impartial and non-commercial organizations would exert a patent influence, and go far toward inducing favorable action by a vast majority of the authorities.

The efforts of the Committee are naturally directed to improving the quality of the screen image and of sound; but this objective can be achieved only after painstaking consideration of the many diverse elements involved in the projection process, ranging from the film stock itself, through the entire chain of visual and sound projection equipment units, to the screen. Obviously, this task will impose a severe strain upon the resources of the Committee. To this end the Committee extends an appeal to the industry generally, and to the full Society membership in particular, for coöperation in submitting any data having a bearing upon this investigation. Other committees of the Society interested in related subjects have already been informed of this program and have been asked to coöperate.

The Committee, as a matter of technical coördination, will endeavor to obtain from each branch of the industry information on projection equipment and methods and their bearing on other devices and processes used by the industry. These data should be widely disseminated in all quarters where they may be used to advantage to increase efficiency and economy.

Other topics that will continue to engage the close attention of the Committee are:

(*1*) Further refinement and extension of projection room lay-outs for small, medium, and large theaters.

(*2*) General auditorium lighting, a topic that invites particularly close attention at this time as a result of the general marked improvement of projection light-sources during the past two years.

(3) Determination of the correct mirror magnification ratio to obtain an acceptably uniform spot for the standard projector aperture with the Suprex arc.

(4) Illumination and sound transmission characteristics of the screen.

(5) Types of screen masking.

(6) Suitable starting acceleration of motors driving the projectors (avoidance of excessive strain and consequent damage to equipment and film).

(7) Projection illumination with reference to color-film.

The last topic is particularly important at this time because of the possible increasing use of color film by the industry. The resultant color upon the screen is dependent in large measure upon the light-source used and the accuracy with which it is controlled. Color-film projection merits special attention upon the score of both quality and quantity of the projected light. In the future, the Committee's recommendations concerning projection light-sources will bear specific notations as to their applicability to black-and-white or color projection.

The Committee is particularly interested in finding a suitable light-meter that may be distributed at a price reasonable enough to induce widespread use. Several sample meters are now under consideration.

H. RUBIN, *Chairman*

J. O. BAKER	J. J. FINN	P. A. MCGUIRE
T. C. BARROWS	E. R. GEIB	R. MIEHLING
F. C. CAHILL	A. N. GOLDSMITH	E. R. MORIN
J. R. CAMERON	H. GRIFFIN	M. D. O'BRIEN
G. C. EDWARDS	J. J. HOPKINS	F. H. RICHARDSON
J. K. ELDERKIN	C. F. HORSTMAN	J. S. WARD

DISCUSSION

MR. WITTELS: Not long ago a new theater was being built outside Minneapolis, and I gave the drawings of the projection room lay-outs to the architect, who immediately recognized their value. I believe he took the lay-out for the size of theater he was building, incorporated in it everything that was needed, and laid out the projection room as the Projection Practice Committee recommended. I think the Committee should know about it.

MR. KENNEDY: The Projection Practice Committee deserves a lot of commendation. All this discussion about light-sources and screen brightness will have to be studied from the ground up and will have to be solved. There are many different kinds of theaters, types of seating arrangements, sizes of screens, projection distances, and so forth, that it seems almost impossible for manufacturers to make machines that will be suitable for all conditions—that is, to provide a certain brightness of screen for any distance—while the projectors and light-sources are all made more or less according to certain standards.

As was stated in the report, there should be greater agreement among the States, which even now agree in respect to certain of the specifications. It is

for this body to establish specifications and to see that the States adopt them and adhere to them. Then the manufacturers could make their equipment conform to those specifications.

MR. JONES: A great deal of the preliminary work of standardization has to be done by the technical committees. When a technical committee has reached a point at which it is ready to recommend a standard, the recommendation must go to the Standards Committee, which will then formulate the proposal in the proper manner. We are now in the course of doing that but, of course, it can not be done hastily. We must proceed in an orderly fashion.

MR. HOVER: I agree that the matter should not be taken care of too rapidly; but I happen to supervise a visual instruction program for the division of safety and hygiene of Ohio, and, to our horror, we recently found out that more than 40 high-school auditoriums had been built during the past three years, with the intention of installing sound equipment in them. The projection rooms that were provided are portable, and are 5 feet square and 7 feet high.

MR. WILLIFORD: In the electrical manufacturing industry there is a very definite program for legislating standards. There is a Uniform Legislation Committee, and a paid staff for inspecting bills presented to the various municipal and state legislative bodies, and when advice needs to be given to those law-making bodies, it is given to them.

I am wondering whether this Society has made adequate provision for getting its standards into the proper hands and watching this legislation—particularly with respect to the American Institute of Architects. In addition to the American Standards Association, we should certainly consider taking advantage of some of these other agencies.

MR. GRIFFIN: It has been recommended that the Committee call the attention of the Association of Electrical Inspectors to the work it is doing to achieve uniform regulations throughout the country. It is a very large organization, whose members have jurisdiction over practically all the theaters of the United States. This is an important step and certainly should result in the Committee's gaining prompt action.

MR. MITCHELL: The Non-Theatrical Committee report touches upon some of the regulations that have been promulgated and applied recently in 16-mm. projection and non-theatrical projection generally. We are making quite a point of the desirability of the Society's recognizing the conditions and striving through some sort of recommendation for uniform legislation. I think the two Committees can work together very effectively on this problem.

MR. CRABTREE: In connection with Mr. Williford's remarks, we had in mind the matter of getting together a sort of compendium of information relating to construction. About two years ago Dr. Jones and I met in conference at Rochester with representatives of the American Institute of Architects. The result was that we were requested to have some Committee or individual prepare the material and present it at one of our meetings, at which it would be discussed. After that, the idea was to present it at several of the regional meetings of the AIA, and after further discussion to publish it in their journal.

We tried to proceed with the formulation of this compendium of information. Mr. Schlanger undertook to handle the architectural side, Mr. Wolf the acoustical, and Dr. Jones the optical. I have been trying to get the three together for the

past two years. Mr. Schlanger has published two papers. Mr. Wolf handed me one yesterday, and I believe Dr. Jones will speak for himself. That is where the matter stands now, but the three papers have not yet been fused together. It is a desirable thing to do, because I believe we have sufficient information at least to prevent such terrific blunders from being made as have just been mentioned.

MR. JONES: If you have comprehended what has gone on at this session you will realize why I have not prepared the paper. Much work had to be done, and the work of the Projection Screen Brightness Committee shows what was done. We can not pull solutions out of thin air, and there is no point in recommending practices without adequate foundations upon which to base the recommendations. We have made progress, as reference to the May JOURNAL will show, and when the paper is finally written, it will contain very valuable information.

MR. MCGUIRE: One of the important purposes of the Projection Practice Committee is to show the interrelation of the various activities of the industry to each other in such a way that the industry will more fully appreciate what the SMPE has been doing as a coördinating body. We must try to show the industry how necessary it is to have some organization function to pave the way toward solutions of the many practical problems in the various departments in the industry. Motion pictures are not made in a single factory as is an automobile. They start out in a given place, go through many vicissitudes, and finally wind up at the theaters. At any point in their travels something can happen that will destroy all that the specialists of the Society have done to perfect them.

At a recent meeting of the Atlantic Coast Section we had an excellent talk on the elimination of flutter. There were diagrams. There was no question that flutter had to be taken out. During the discussion it was pointed out that if the sprocket teeth of the projector were worn, there would still be flutter. What is the use of sound engineers taking out the flutter if it comes back into the theater by another avenue?

Although the sound engineer is expected by this time to be a specialist in his particular work, he must take a lively interest in the other activities of the industry, so that when flutter is taken out by him, it will stay out. We are all dependent in the end upon the success of the industry as a whole, and anything that injures the quality of the finished product in any way will to that extent undo the work of other departments of the industry.

Therefore, if we can coöperate more fully, coördinate more, demonstrate how necessary such coördination is, more interest will be taken in the Society and its technical committees. Exhibitors take very little direct interest in the Society. We have made a number of attempts to get them to attend these meetings but the response has been extremely limited.

It is a tremendous job to show the industry clearly, and make it understand, how necessary it is to coördinate all these interrelated activities. We must have the coöperation of the industry itself. But we can not do a great deal until we get real financial support in this field, and we are not getting it. Mr. Williford spoke a little while ago about doing this and doing that—all of which require considerable money. All the Projection Practice Committee can do, for instance, is to make recommendations, for inducing and directing legislation. Perhaps a more complete understanding of what we are doing will prompt the necessary coöperation of the industry and speed up the activities of the Society.

REPORT OF THE STANDARDS COMMITTEE*

During the past winter the main activities of the Standards Committee have been confined to the preparation of a new Standards Booklet in which will be incorporated several corrections, and which, it is hoped, will present the standards in a more usable form.

The Standards Committee is exceedingly fortunate in having the able assistance of Mr. G. Friedl who has consented to undertake a large part of the work of revising the drawings. Most of the drawings have been reviewed by the Committee, and the improvement in the manner of presentation is apparent to all.

The two proposals mentioned in the last report of the Committee, have been put into practice, *viz.:*

(*1*) That the Engineering Vice-President be requested to appoint several European members of the S. M. P. E. to the Standards Committee, in order that they may establish a direct liaison between this Committee and the European Committees.

(*2*) That copies of minutes of the meetings of this Committee be sent not only to such foreign members, but also to the secretaries of other Societies interested in motion picture technology and standardization both here and abroad, and to a selected list of persons who might be expected to offer criticisms or suggestions.

Acceptances have been received from the following foreign members appointed to the Standards Committee by the Engineering Vice-President: I. D. Wratten (England); F. C. Badgley (Canada); A. Cottet (France); L. N. Busch (Germany); L. de Feo (Italy).

The unfortunate situation in regard to the 16-mm. sound-film standards appears to be clearing up to a great extent. The Dutch Standards Committee adopted the S. M. P. E. standards last fall, and on February 25, 1936, a meeting was held in London at the Middlesex Guildhall with Lord Riverdale as arbitrator to decide which standards should be adopted by the British Standards Institution. On March 20, 1936, it was announced that the award had been made to the S. M. P. E. standards so far as the position of the sound-track goes.

The chief items under discussion at the present time are as follows:

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* Presented at the Spring, 1936, Meeting at Chicago, Ill.

(*1*) *Screen Brightness.*—It is hoped that the series of papers presented at the Fall, 1935, Convention by members of the Projection Screen Brightness Committee, under the Chairmanship of C. Tuttle, and published in the May issue of the JOURNAL, will offer some practical basis for standardization.

(*2*) *2000-Ft. Reels.*—The Standards Committee has given its initial approval and final approval to the 2000-ft. reel recommended by the Academy of Motion Picture Arts and Sciences. The announcement has been made, according to the rules of the Society, in the April, 1936, issue of the JOURNAL, and we are awaiting discussion from the membership. If the communications in regard to this are substantially favorable, the matter will be submitted to the Engineering Vice-President, who will present it to the Board of Governors for approval.

The deletion of the definition of "reel" as approximately 1000 feet of film from the official glossary is in the same situation.

(*3*) *16-Mm. Sound Lead.*—The German standard for the lead of the sound over the picture in 16-mm. sound-film is 27 frames. The S. M. P. E. standard is 25 frames. A compromise proposal of 26 frames has received initial approval by the Standards Committee and will be submitted for final approval very shortly.

E. K. CARVER, *Chairman*

F. C. BADGLEY	R. E. FARNHAM	G. F. RACKETT
M. C. BATSEL	C. L. FARRAND	W. B. RAYTON
L. N. BUSCH	H. GRIFFIN	C. N. REIFSTECK
W. H. CARSON	R. C. HUBBARD	H. RUBIN
A. COTTET	E. HUSE	O. SANDVIK
L. DE FEO	C. L. LOOTENS	H. B. SANTEE
A. C. DOWNES	W. J. MACNAIR	J. L. SPENCE
J. A. DUBRAY	K. F. MORGAN	A. G. WISE
P. H. EVANS	N. F. OAKLEY	I. D. WRATTEN

REPORT OF THE COMMITTEE ON PRESERVATION OF FILM*

During the early part of last year, the Carnegie Foundation donated five thousand dollars for the purpose of studying methods of preserving film records. It was stipulated that this money was to be administered under an advisory committee named by the National Research Council, and that the study should be conducted at the National Bureau of Standards.

A little later The National Archives transferred additional money to the Bureau for this purpose, and the project has been proceeding with interesting results. The membership of the advisory committee and the general nature of the project was covered in a paper presented by the Chairman last fall.[1] The present reference to the project seems necessary as a foundation for this report.

The Committee on Preservation of Film met at the Wardman Park Hotel, Washington, on October 24, 1935, and agreed, rather than to set up a research project of its own, to act as a sort of review board for the work being done at the Bureau of Standards, each member to make such individual contribution to the work as he could. The Chairman conducted some correspondence with the members of the Committee, but devoted most of his time in this capacity with the Bureau. However, on April 16th the Committee met at Washington in an all-day session, with the following members in attendance: John G. Bradley, *Chairman*, J. I. Crabtree, V. B. Sease, W. A. Schmidt, A. S. Dickinson, C. L. Gregory, G. R. Goergens (substituting for R. Evans).

It is significant that with the exception of one member this meeting represented the full membership of the Committee. Meeting with the Committee were the following guests: E. K. Carver, of the Eastman Kodak Company; H. T. Cowling and G. C. Henry, of The National Archives; B. W. Scribner, John R. Hill, J. E. Gibson, and Meyer Reiss, of the Bureau of Standards.

The project outlined for the Bureau of Standards as reviewed by the Committee at this meeting is referred to as the "twelve-point program," as follows:

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* Presented at the Spring, 1936, Meeting at Chicago, Ill.

(*1*) The effects of humidity and temperature and rapid atmospheric changes upon nitrate and acetate film, to determine the optimum atmospheric conditions for storage and use of films.

(*2*) Determination of the effects of residual hypo or other active materials in the film upon the stability of the film base and the image. Also study of refixing and washing to remove residual chemicals, to include study of the feasibility of using distilled water in final washing and the suitability of other available water. Finding best practice for fixation, washing, and drying.

(*3*) Type of tempering unit required for bringing films from low temperature storage conditions to projection room atmosphere without condensation of atmospheric moisture. Also conditioning required to prepare films for return to storage atmosphere.

(*4*) The value of camphor or other restoratives in the storage containers to retard the loss of flexibility.

(*5*) The value of protective coatings and other treatments for prolonging the life of films; also methods of reconditioning old films. This to include study of surfacing films, cleaning compounds, and so forth.

(*6*) The merits of hermetic sealing *vs.* vented containers in the storage of films.

(*7*) Expansion and shrinkage of the base and the gelatin coating, with consideration to the adhesion of the gelatin to the base.

(*8*) The type of material for film cores and containers, to find the material least affected by decomposition products of nitrate films and least likely to harm the film wound upon it.

(*9*) The character of decomposition products or other gases given off by the films under different aging treatments.

(*10*) The development of specifications for films to be stored. The requirements to be based upon results of the studies of factors affecting the life of films.

(*11*) A study of acetate negative base.

(*12*) A study of the effects of light and heat upon motion picture film during projection.

It should also be pointed out that the results of work done by the Bureau can not be published until officially released. We are glad to say, however, that nothing was withheld from the members of this Committee and that a full report will be published later. We are also happy to have the privilege of including in this paper the following preliminary report on this project, subject to revision after further study and experimentation.

TESTING METHODS

When the work was initiated there were no well known test methods for use in connection with films. Almost everyone realized that nitrocellulose film was unstable; but just how long it would last under optimum storage conditions, and what these optimum storage conditions were, no one knew. As for the cellulose acetate film, being

a comparatively new product, no records of natural aging were available, and very little was known about its lasting qualities. Consequently, a large part of the Bureau's work had to be directed toward developing tests applicable to the problems at hand. This is more or less a continuous process, and new methods are constantly being developed. Several possible tests were tried which were later abandoned. But the following explains to some extent a few of the more successful and useful tests, and gives a general idea of the work done.

Folding Endurance.—A small, hand-operated, Pfund type of folding machine was used. The film was cut into strips to fit the machine, heated in an oven for definite periods of time at 100°C., then placed into the machine and folded back and forth until broken, the number of folds being counted. The nitrate samples showed the greatest loss, and after a comparatively short aging period became too brittle to test. The acetate samples retained a much higher percentage of their original folding strength, and at the end of no heating period did they show a loss as great as that of the nitrate samples.

Loss of Weight.—Samples of both nitrate and acetate film were heated for definite periods of time in a dry oven at 100°C. These samples were weighed before and after the heating treatment, and the loss of weight determined. Both types of film showed a continued loss with longer heating periods, the loss of the nitrate being much greater. The acetate suffered its greatest loss during the first few hours, and showed only a slight decrease thereafter.

Viscosity.—In following the effects of accelerated aging upon both acetate and nitrate films one of the most useful chemical tests found so far is the measurement of viscosity. This test consists in dissolving a small sample of the film in a definite volume of acetone, and measuring the time of flow in an Ostwald viscosity pipette. The viscosity is determined by expressing the time of flow of the solution relative to the time of flow of the solvent, which, in this case, is acetone. According to some authorities, for equally concentrated solutions (below certain concentrations) of long chain molecules like rubber and cellulose, the viscosity depends only upon the molecular weight. Consequently, any breakdown of the molecular structure should be detected by a lowering of the viscosity.

Here, too, the nitrate samples showed a greater loss upon heating, showing almost complete decomposition at the end of a comparatively short heating period. The loss sustained by the acetate was very small. These results were obtained from heat treatments in an

oven-dry atmosphere. When the samples were heated in an atmosphere of very high humidity deterioration was accelerated.

pH Determination.—The free acidity of the film samples was determined by making use of *p*H. *p*H is expressed as the negative log of the concentration of the hydrogen ion. The lower the *p*H, the greater the free acidity; the higher the *p*H, the lower the free acidity. Nitrate film showed a decrease in *p*H upon heating much greater than the acetate. The *p*H of old deteriorated nitrate film was very low.

Copper Number.—This is a standard test used in determining the deterioration of the basic cellulose of paper and was made use of in the film experiments. It was found unsuitable for use with the nitrate film, but worked very well with the acetate. The acetate samples showed a slight increase in copper number for the longer heating periods.

Deterioration of Emulsion.—In determining the probable causes of the deterioration of nitrate film, the effect of the loss of camphor was investigated. It was found that old deteriorated nitrate film still contained a fair share of its original camphor. This seems to indicate that the deterioration of nitrate film is not caused by its loss of camphor. It is a combination of other factors. Nitrate film is at its best an unstable product, and anything which tends to increase its oxidation and hydrolysis will hasten deterioration. There was found a close parallelism between the amount of NH_3 (ammonia), the *p*H of the gelatin, and the viscosity of the base.

Humidity and Temperature.—The effects of humidity and temperature and rapid atmospheric changes upon both types of film have been investigated. Rapid or extreme variations of temperature and humidity were found to be detrimental. Probably the best conditions for storage would be very low temperature and humidity. However, a temperature of 50°F. and a 50 per cent relative humidity is recommended as reasonable for all practical purposes.

Residual Hypo.—It has been found reasonable to expect and demand a content of thiosulfate sufficiently low to give a negative test. This thiosulfate can be eliminated by washing in distilled water, and detection technic can be developed following well known methods.

Tempering.—Extensive or elaborate tempering units are not necessary. Tempering can be accomplished by means of a sealed container, preferably a small container for two or three reels at a time.

Summary.—All the above-given results attained so far show very much greater stability for the acetate film than for the nitrate, and while it is not possible to predict just how long the acetate would last under natural conditions it appears to be a very promising material for permanent records. The only point in which acetate seems less

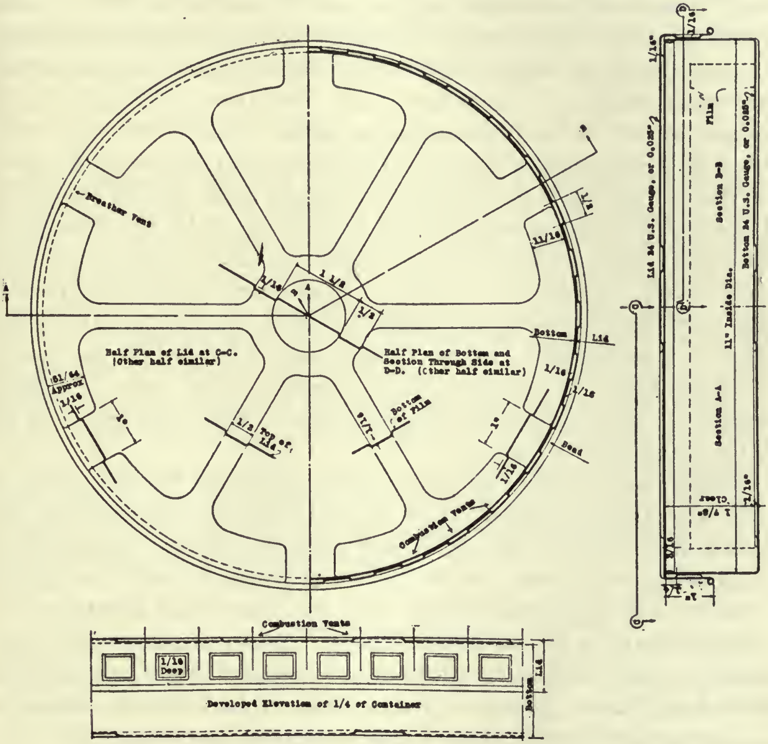

FIG. 1. Plan of film container.

desirable than nitrate film is its susceptibility to changes in relative humidity. However, it is believed that the expansion and contraction is not a serious problem under controlled temperature and humidity. Distortion difficulties formerly encountered apparently resulted from incorrect storage and use of the film, lack of air-conditioning, *etc.* Under plans set up for preservation of film in The National Archives Building, for example, this problem should be of no

great importance. Other phases of the work being done at the Bureau of Standards will be reported on later.

FILM CONTAINERS

The Committee at the April 16th meeting gave considerable time to a study of film containers for the storage of nitrate film. In this study it was undertaken to render a specific service to The National Archives. Under plans adopted for film storage cabinets, individual compartments for single reels of film have been provided, with a maximum height of 2.5 inches. The limitations of height in the compartments necessitated either a rather shallow lid that would come off when pressure was set up inside the can, or a vented type of lid that would allow the pressure to escape while the lid stayed on. A container of the latter type has been designed by the Division of Motion Pictures of The National Archives, and samples have been constructed. This allows, first, a 0.7 square-inch ventage for "breathing" purposes when the can is in a state of repose, and additional side vents of 1 square-inch capacity which come into play in case the lid is partly lifted by pressure on the inside of the can. Hermetic sealing for nitrate film was disapproved. The construction of the can is illustrated by Fig. 1.

During the afternoon the Committee visited the Bureau of Standards, where one thousand feet of old and badly deteriorated film was placed into this can and set on fire after the lid had been securely clamped by strong iron bands. The iron bands, however, permitted the lid to lift approximately one inch, the dimensions simulating the compartments in the storage cabinets. Heavy white smoke issued from the vents in the side of the can for approximately four minutes, with considerable pressure. Other than a black residue being deposited upon the inside of the can no other damage was noted.

A second roll of film was placed into the same can, a little drier than the first roll, and again set on fire. Instead of smoke issuing from the can, a fire was started immediately and continued for approximately two minutes. The flame was thrown out in all directions for several feet, with great violence and noise. The pressure was so great that one side of the can was lifted, creating a vent in excess of the vent provided in the lid of the can. On this evidence the Committee concluded that the vents should be made slightly larger to take care of maximum violence resulting from combustion.

The Committee gave thought also to the material from which the

can should be made. The Bureau of Standards had previously recommended that only acid-resisting material should be used, with a possible choice between stainless steel and aluminum. Although aluminum is resistant to oxides of nitrogen, its tendency to flake and dust and its susceptibility to abrasions mitigate against its use for storage of motion picture film. The Committee concluded, therefore, that if aluminum were used the film should be enclosed in black photographic paper. Its preference, however, was for stainless steel, Pyrex glass, or some acid-resisting material other than aluminum.

ACETATE NEGATIVE

The question of the use of acetate negatives was given consideration by the Committee. The National Archives is interested in this as a basis for determining future policy in its choice between use of nitrate negatives or acetate. In view of the seeming stability of acetate film, its use for future duplications of archives seems advisable. The question was asked, "Can the film manufacturers furnish acetate base for duplicating negatives?" It was the thought of the Committee that reasonable assurance can be given at this time for a practical acetate negative for use under controlled conditions set up by The National Archives. Its greatest weakness is its tendency to buckle and distort, which would necessitate special handling. The representatives of the film manufacturing companies promised to give further thought to a pre-shrunk base.

MISCELLANEOUS

The Committee recommended, in addition to the work being done at the Bureau, (*a*) that the phrase "preservation of film" be defined to include "preservation of film records" by all possible means, including duplication; (*b*) that caution be taken in removing all possible dust from the film before handling, rewinding, *etc.*; (*c*) that further thought be given to renovation and salvaging of old motion picture film, restoration of faded images, *etc.*; (*d*) that careful chemical tests be made for injurious foreign matter before accepting film for storage and (*e*) specifications for processing and handling new film; (*f*) optical printers for shrunken film, (*g*) filing aids, storage of safety film, *etc.*

The Committee extended its thanks to the National Bureau of Standards for its helpful contributions in the field of film preservation and for its fine spirit of coöperation with the Committee.

J. G. BRADLEY, *Chairman*

J. I. CRABTREE
A. S. DICKINSON
R. EVANS
C. L. GREGORY
T. RAMSAYE
V. B. SEASE
W. A. SCHMIDT

REFERENCE

[1] BRADLEY, J. G.: "Motion Pictures as Government Archives," *J. Soc. Mot. Pict. Eng.*, **XXVI** (June, 1936), No. 6, p. 653.

DISCUSSION

MR. CRABTREE: The Society is greatly indebted to Captain Bradley for assembling the available data, and particularly for stimulating further research through the medium of the National Research Council. It is unfortunate, however, that in designing the Archives Building, the space for storing records was placed above ground. The architects have ignored the possibility of aerial bombardment. It would seem desirable, if any additions are to be made to the Archives Building, that provision be made for storage underground at a distance beyond that penetrable by aerial bombs of a size such as we may imagine will be designed within the next, say, fifty years.

Captain Bradley intimated that film records could be perpetuated, by duplication, for the life of the human race. That is, of course, assuming that 100 years or more from now anybody will be interested in duplicating them. If we are concerned with perpetuating records for hundreds or thousands of years, it would seem that some consideration should be given to making records upon metal bands, such as gold or platinum, which could be buried underground. This would insure (in the absence of vandalism) that the people 5000 years from now would have some sort of record; whereas it is doubtful, even with the scheme outlined by Captain Bradley, that they will have any record at all if we anticipate the aerial wars that may possibly occur in the future.

MR. MITCHELL: Are there any data as to the keeping qualities of collodion emulsion as compared to gelatin emulsions? I understand that there is a proposal that a special emulsion such as collodion be used for important records instead of gelatin. It would require more light for printing, but if the keeping qualities were more desirable, it would be worth while to make the effort.

MR. BRADLEY: The Committee at the Bureau of Standards is made up of two chemists, a physicist, and two paper men. The project has been financed for a year, and we have enough funds left from the first year to continue for another six months. We hope to receive additional funds for carrying on the project for at least three years. The product you mention has not been made a part of the present project, but we hope to investigate it later.

MR. MATTHEWS: In connection with the Franco-Prussian War of 1870, military dispatches prepared photographically on thin collodion sheets were sent out from Paris by pigeons. Dr. Bendikson, at the Huntington Library at San Marino, Calif., had occasion recently to examine those records, which were about 65 years old, very carefully. He found that they were in an excellent state of preservation, and should keep for many, many years to come. His report is published in the *Library Journal*, **60** (1935), p. 15.

REPORT OF THE COMMITTEE ON NON-THEATRICAL EQUIPMENT*

The use of motion pictures for non-theatrical purposes has increased with such amazing rapidity that it is becoming quite difficult to keep up with the developments. The great increase has been in the use of 16-mm. film, particularly 16-mm. sound-film, which has been so rapid that 16-mm. motion pictures have just about reached the stage at which they can be called industrial and educational rather than merely amateur.

16-Mm. Test-Film.—While at least two companies are putting out 16-mm. sound-films containing constant frequency and musical recordings, there has been experienced a growing demand for an official SMPE 16-mm. test-film similar to the 35-mm. test-film. Such requests have been received consistently from abroad, and in view of the situation existing with respect to the SMPE and the DIN standard, it is urged that the *immediate* production of an official SMPE 16-mm. sound and picture test-film would materially strengthen the prestige of the SMPE standard. The members of this Committee regard this matter as very important.

Referring to the use of DIN prints on SMPE type machines, at least two American companies supplying 16-mm. sound projectors to foreign outlets have prism or mirror attachments. These attachments are available at very nominal prices, and permit DIN prints to be used on SMPE projectors. It is also reported that subjects normally printed according to the DIN standard can very often be obtained according to the SMPE standard. The Standards Committee is endeavoring to remove the present unfortunate differences now existing between these two standards, and their activities are being followed most anxiously. The recent decision of the British Standards Institution to adopt the SMPE standard is most encouraging and it is hoped that an ultimate solution will soon be found for the adoption of a world standard.

The Industrial Field.—Motion pictures, particularly 16-mm. silent, have experienced greatly widened application in the industrial field. It was here that the full possibility of showing 16-mm. film to large

* Presented at the Spring, 1936, Meeting at Chicago, Ill.

audiences was first realized. With the introduction of sound and with the availability of 16-mm. sound recording, processing, and reproducing equipment of extremely high precision, the use of 16-mm. sound-film for advertising purposes has increased tremendously. It is reported that one of the large concerns manufacturing motor cars has, for the past two years, spent a major portion of its entire advertising appropriation on the production and showing of 16-mm. talking pictures. The success of these showings has persuaded every leading motor-car manufacturer to employ talking pictures for business advertising. Many leading companies in other lines of endeavor have duplicated and are duplicating this same experience.

Ordinances and Similar Restrictions.—The extent of the use of movies for non-theatrical work may be gauged by the fact that numerous ordinances have been passed in various parts of the country regulating such showings, or projectionists have been faced with obsolete regulations intended to cover theatrical shows only. As may be expected, wide variation is encountered. Some ordinances recognize the difference between theatrical and non-theatrical showings, and especially recognize the fact that equipment approved by the Fire Underwriters imposes no hazard in projection, so that there is no legitimate reason for imposing restrictions. Such ordinances are, in general, eminently fair, while others are most restrictive.

This matter is assuming such proportions that, in some localities at least, the situation is rather critical. Therefore, the following is offered with the thought that the Society might officially recognize the situation and perhaps sponsor a national movement to offset unfair and restrictive legislation. Another suggestion is that the Society offer a model ordinance that might be called to the attention of authorities contemplating the necessity of covering this field. At least the distinction between theatrical and non-theatrical uses should be clearly specified.

For instance, the regulations in Jacksonville, Fla., are so restrictive that any person owning a sound projector or a silent projector of capacity greater than 500 watts is legally liable to a fine of $100 for showing pictures in his home if he does not have a $16 license. (An amendment passed August 28, 1934, and published in the *Florida Times-Union*, September 6, 1934, states that "projectors containing sound and amplification apparatus or light-sources exceeding 500 watts shall not fall within the range of amateur projection.")

The ordinance does not distinguish between 16-mm., 35-mm., or

any other width; it arbitrarily covers *any* sound projector, and fails to recognize that in many schools, for instance, teachers and even students operate 16-mm. projectors up to 1000-watt capacity in perfect safety.

In contrast to this, the Chicago ordinance may be cited as fairly recognizing the safety of 16-mm. projection due to the fact that the film is made of slow-burning (acetate) base. The following quotations from the Chicago code are self-explanatory. *Ordinances, Article VII, Electrical Code,* concerning non-professional motion picture projectors and equipment, contain, among others, the following provisions:

Section 1669. **Definition:** *Miniature Non-Professional Motion Picture Projector:* A non-professional motion picture projector whose construction provides for the use of films of a width less than one and three eighths ($1^3/_8$) inches, which film is regularly supplied only as slow-burning (acetate cellulose or equivalent) film.

Section 1674. **Fireproof Booth Unnecessary:** The location of a non-professional motion picture projector in a fireproof booth shall not be required.

Section 1676. **Permit Required:** A permit for each location, as provided in section *1638* of this code, shall be first issued for the installation and use—whether permanent or temporary—of any non-professional motion picture projector, *except a miniature non-professional motion picture projector,* and also except any projector installed in a location for projection elsewhere than in an assembly hall or an assembly room, provided that these exceptions shall not apply where the means afforded for connection to supply power are not in accordance with section *1676.*

Section 1677. **Licensed Operator Required:** When located for projection in assembly halls or assembly rooms, non-professional motion picture projectors, *except miniature non-professional motion picture projectors,* shall be operated by licensed operators, as provided for in section *2776* of this code.

Section 2776. **Moving Picture Machine Operators—License Required; Applications for License; Examinations:** It shall be unlawful for any person to operate a moving picture machine or device for any public or private gathering without first having obtained a license as a moving picture operator in the manner hereinafter set forth; *provided, that this article shall not apply to the operation of any moving picture machines or devices of a miniature type for home, lecture, and similar purposes requiring 16-mm.* slow-burning type film."

Educational.—A quarter-century ago in America, the pioneer automobilist found himself seriously handicapped by the absence of suitable roads. The highway authorities, when approached, replied that they saw no reason for building wider, straighter, and smoother roads for automobiles when practically no automobiles existed. No automobiles, no roads. It seemed like a vicious circle, from which there was no escape. Yet an escape was found. Today automobiles

are numbered in the millions, and road miles have multiplied beyond the fondest dreams.

A similar situation has prevailed with respect to the educational film. Some educators have demanded that commercial film producers guarantee an ample and perfectly correlated supply of teaching films before equipment and films are bought by the schools. The film producers have maintained that their production must be for a profitable market; otherwise there could be no production. The argument has also been put forward that the educators themselves do not know what they want in the line of educational films. Equipment manufacturers have tried to find a way out of this impassé in order that the school market might be opened up for equipment sales.

The solution seems very much the same as that of the automobile and the roads: a gradual process of adaptation. Film producers have gone into education. Schools have gone into film production. Equipment manufacturers have gone into both film production and education, and finally a common meeting ground has been found in such clearing house associations as the National Academy of Visual Instruction, which only recently merged with the Visual Instruction Section of the N. E. A. The final unification of all organized visual instruction forces in the United States in a single, well-knit organization promises an auspicious future for the organization.

The step taken by the American Council of Education and the formation of the American Film Institute[1] in Washington have been the foremost steps of late to create a greater interest in the use of visual instruction materials. The Rockefeller Foundation in New York is sponsoring the more extensive use of films and 16-mm. equipment in the school curriculum.

The Federal government is taking a very active interest in the use of motion pictures for educational purposes, and a number of reports have been prepared covering these investigations. A compact summary of the present status of the Federal government's interest in educational films discussed the five-point aim of the Educational Council study, the ten steps necessary to reach the goal, and the five-point project of the American Youth Commission.[1]

The proposed American Film Institute which has already been started, has set out in several directions. In the first place, it is expected to compile in catalog form all the present available educational material, according to how it fits into the curricula, and list them in a much simpler form than now exists. The American Film

Institute will be a central headquarters for information as to film material available, and within a very short period of time it will be necessary for schools all over the country merely to write to the headquarters in Washington for one catalog, which will give complete information regarding all films available and upon what basis: rental, purchase, free, *etc.* There are several other endeavors, of course, of the American Film Institute, such as increasing the use of motion picture equipment as an instructional medium, organizing data relative to the present use of the equipment in the school market, how extensively 16-mm. sound is being used, whether sound or silent equipment is best suited for teaching purposes, *etc.*

The *Educational Screen*, in coördination with the Department of Visual Instruction of the N. E. A., has recently sent out a questionnaire to a large group of school principals throughout the country, asking what type of material they use; how they use it; what reasons they have to offer as to why visual instruction does not progress in their school system, if it has not; what suggestions they have for creating a greater interest in the use of visual aids; and many other such questions. The United States Department of Education, under Mr. Studebaker's signature, is also sending out a questionnaire to superintendents all over the country, asking similar questions, to get a good picture of the visual instruction situation in the United States at the present time.

According to an excellent and comprehensive survey recently completed by Dr. F. E. McCluskey,[2] there are approximately 205 to 225 visual instruction departments in municipal school systems, the equipment of which varies all the way from six dozen slides to such splendidly administrated resources as we find in the City of Philadelphia.

State visual instruction centers are usually sponsored by the state universities, but sometimes administered by the State Department of Education. There are approximately 28 such centers. Ten years ago 16-mm. educational film was practically unknown, but it now practically outranks the older 35-mm. material in all the more advanced state centers.

Museums, both city and state, frequently maintain extensive film service. Twenty-two such museums are listed by the National Academy of Visual Instruction. The largest among them is the New York Museum of Natural History.

Individual school libraries are being built up in a number of centers

on the correct theory that motion picture film should be instantly accessible, just as maps or reference books.

Federal government departments such as the Bureau of Mines, Department of Agriculture, Department of the Interior, *etc.*, offer free films to schools. The Navy Department offers free 16-mm. disk talkie films.

Equipment manufacturers have built up libraries of informational films, generally with the coöperation of educational authorities. Films such as Raymond L. Dittmar's *Living Natural History Series*, made by the Curator of the Bronx Zoölogical Garden, and other such series, are now available. Commercial producers of teaching films do not, as a rule, rent or loan the films to schools, but offer their products for outright sale.

Commercial sources of "free" films and other visual aids are exceedingly numerous.[5] General Electric Company offers a 32-page illustrated catalog, free. Goodyear Tire and Rubber Company, Caterpillar Tractor, Petrolagar, and other such commercial concerns make their films available *gratis* to school systems. The larger automobile companies, such as Chrysler, Pontiac, Hudson, General Motors, Fisher Body, and many others, likewise have new 16-mm. sound-films available free to schools. The distribution of commercial films is generally handled by sponsors such as the Y. M. C. A., National Council Motion Picture Bureau, *etc.*

A number of productions have been made specifically to fulfill the requirements of the educational field. In this country the subjects put out by Erpi, in conjunction with the University of Chicago, have achieved international recognition. A development in France was recently reported[6] on the making of concert picture shorts. These shorts are made in duplicate, of eminent artists such as Paderewski, Kreisler, and others. One picture is accompanied by artistic scenes to enhance the mood of the music, while the other is a technical picture showing the musicians' fingers, *etc.*, to demonstrate to advanced students the technic involved. The Committee has reported previously the work done on extracting certain episodes from standard motion picture releases and re-editing them to form subjects of educational nature. This idea is apparently progressing, and would seem to present many possibilities if handled effectively. At the same time, the conviction is growing that the best educational subjects are those that have been specifically designed and made to a carefully worked out pedagogical script.

There is no longer any division of opinion as to whether 16-mm. or 35-mm. equipment should be used in the schools. Although formerly 35-mm. was used solely, it is now very rapidly being supplanted by 16-mm. Such large school systems as those in Los Angeles, San Diego, Chicago, and many others that formerly used 35-mm. are now using 16-mm. apparatus exclusively. The February, 1936, Convention of the N. E. A. was especially enthusiastic about visual education in general and movies in particular.

It is interesting to know that the motion picture has been used in the school ever since film existed. In fact, the motion picture owes its birth to educational and scientific research, rather than to the theater. However, the theater's claim to the film proved so much more profitable than that of the school that the theatrical field very soon eclipsed the educational market. Prior to the event of the 16-mm. film, the attempt of the educator to use motion pictures ran into too many obstacles for it to become a large factor in the school market. However, since the advent of 16-mm., all the obstacles of fire hazard, improper material, inadequate equipment, heavy equipment, *etc.*, have been eliminated, and these have been the largest contributing factors for the very extensive use of motion pictures in the schools at the present time.

Libraries.—The growth of 16-mm. libraries, particularly sound-film, is extending rapidly, and already many hundreds of 16-mm. sound subjects are available for rental. Reports indicate that in the near future many thousands of such subjects will be available; the growth and use of 16-mm. sound-film for educational, industrial, and entertainment purposes has increased so very rapidly that wide-awake producers are becoming more and more alive to the possibilities of this field.

Standards.—There seems to be a satisfactory agreement between all members of this Committee, representing various manufacturers, that the following proposal be presented to the Standards Committee for consideration either as a standard or as a recommendation for approved practice:

A screen intensity of 6 foot-candles is satisfactory for sub-standard projection where a screen of relatively high specular reflection is employed (for example, a beaded type of screen). An intensity of 10 foot-candles is recommended for the satisfactory projection of sub-standard pictures when using a screen of diffusing characteristics (such as a matte white screen). The figures given cover the projection of black-and-white film of average density.

The same intensities are regarded by some members of the Committee as satisfactory for the projection of 16-mm. Kodachrome, but it would seem desirable to suggest at least 8 and 12 foot-candle intensities respectively for such applications. In this connection, reference is made to Fig. 1, covering the relation between screen size, foot-candle intensity, and total screen lumens.

Considerable work has been done by the Committee on Non-Theatrical Equipment in investigating the various suggestions and recommendations made as to the methods of rating 16-mm. projectors. It is generally conceded that some sort of rating by means of

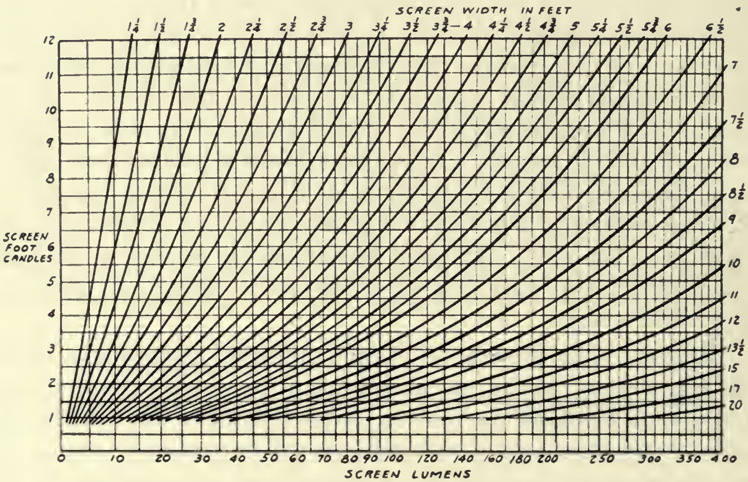

FIG. 1. Chart of screen illumination and screen width.

total screen lumens, measured under carefully standardized conditions, represents the most equitable form of rating. The objection, however, is raised that such rating is relatively unfamiliar to most persons, and that there is not yet any agreement as to the methods to be employed in making such rating. The suggestion is offered that the foregoing foot-candle specifications, while not affording complete specification, do cover the practical requirements of the non-theatrical field in a satisfactory manner. Foot-candle meters of reasonable accuracy are widely available, and it is a relatively simple matter to measure foot-candle intensity with sufficient accuracy for average practical purposes. It is accordingly recommended that each projector manufacturer furnish data in the form of curves,

tables, or as he may otherwise see fit, giving the sizes of screens recommended for use with the various models of his projectors with the two general types of screen suggested.

It is rather felt by the various members of this Committee that a general recommendation of this type not only covers practical requirements satisfactorily, but avoids arbitrary ratings of projectors that might be interpreted to the detriment of some particular products. In other words, some preliminary form of standard is deemed desirable, but complete and restrictive specifications should not be made until the subject has been investigated more exhaustively.

R. F. MITCHELL, *Chairman*

D. P. BEAN	H. A. DEVRY	R. C. HOLSLAG
E. W. BEGGS	E. C. FRITTS	E. ROSS
F. E. CARLSON	H. GRIFFIN	A. SHAPIRO
W. B. COOK		A. F. VICTOR

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REPORT OF THE COLOR COMMITTEE*

The Committee submits herewith a supplement to the original Glossary of Color Photography[1] in which a few terms are redefined and a few new ones added.

In the printing trade, it has been customary for years to use the names "red," "green," and "blue" for the colors of the taking filters, but to speak of the corresponding subtractive printing colors as "blue," "red," and "yellow." These latter names are, of course, poorly chosen, and have caused no end of confusion. The motion picture industry will do well to head off similar confusion by adopting different names for the subtractive components. It would be logical and reasonable to speak of these subtractive printing colors as "minus-red," "minus-green," and "minus-blue." Such terms are objectionable both because of their length and their negative nature. The names "magenta" and "cyan" have been proposed in place of "minus-green" and "minus-red," respectively. Retaining the name "yellow" for the "minus-blue" component, the three subtractive components become "cyan," "magenta," and "yellow," corresponding respectively to the red, green, and blue taking filters. Magenta is very well established as the name of a definite color, and there is no question about its suitability. "Cyan," as a name, has not been so well established; but no more suitable name has been suggested. It is widely used in the aniline dye industry, is short, and is described in Webster's dictionary as "a hue between green and blue." The Committee, therefore, recommends the general adoption of the word "cyan."

A number of multi-layer color processes have been proposed; several of them have been worked on; and certain of them are in commercial use. The terms used in this field are in need of clarification. The word "bi-pack" is understood to mean two films placed in contact, generally face to face, and a "tri-pack" is understood to mean three films in a "sandwich" arrangement. In the usual bi-pack, or tri-pack, the individual films or layers of emulsion are readily separable. In contrast with these, the word "monopack" has been used to indicate an arrangement in which several layers are integrally joined to-

*Presented at the Spring, 1936, Meeting at Chicago, Ill.

gether in manufacture so as to be physically inseparable. This term is generally regarded as inadequately descriptive; rather the adjective "integral" should be used, as an "integral bi-pack" or an "integral tri-pack," to describe two or three layers that are not physically separable.

The new Kodachrome process, which, according to the above-given definition makes use of an integral tri-pack, is the first commercialization of a process coming under a classification described by Wall[2] as "developed color." It is more accurate to speak of "color developers" and "color developer processes" and, therefore, the use of these latter phrases is recommended.

The Gasparcolor process is of the type characterized by the fact that a dye distributed uniformly in the emulsion layer is selectively discharged under the control of a silver image. For processes of this kind the name "catalytic bleach" is sometimes used, but the preferred and recommended term is "selective dye bleach."

Dr. Forsythe, Director of Research of the General Electric Co., at Nela Park, has recommended a revised definition of "effective wavelength" and of "black body."

The Color Committee would like also to recommend to, and impress upon, the Society the great importance of establishing more uniform conditions in respect to viewing-screens throughout the industry. This matter is important enough in black-and-white projection, but is even more important in the projection of natural color pictures. The whole matter has been difficult from a practical point of view in the past years because of the widespread use of radically different types of light-sources. The tendency in theaters today is strongly in the direction of arc lights of high intensity and high color-temperature. This Committee, therefore, urges the Society to study the findings of the Projection Screen Brightness Committee and to set up a standard of screen brightness for the industry. This important work should be vigorously publicized, and the superior quality to be achieved by adhering to such a standard brought vigorously to the attention of producers and exhibitors. Supplementing the standard of screen brilliance, a specification of the most desirable spectral quality of the projection light should be established from the point of view of good color rendition.

J. A. BALL, *Chairman*

W. H. CARSON	C. H. DUNNING	H. W. MOYSE
O. O. CECCARINI	R. M. EVANS	A. WARMISHAM
	A. M. GUNDELFINGER	

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SUPPLEMENTARY GLOSSARY OF COLOR PHOTOGRAPHY

Beam Splitter, or **Fractional Light Diverter**—An optical system so arranged as to reflect and transmit portions of a light-beam along different optical axes.

Black Body—1. A body which when heated radiates ideally according to fundamental physical laws (*i. e.*, Planck's radiation law) relating energy, frequency, and absolute temperature. The properties of incandescent tungsten or carbon approximate those of a black body. 2. A body which absorbs all light incident upon it.

Bleach—1. (*v.t.*) To make white or whiter, by a chemical process or by exposure to intense radiation; 2. in photography, to remove, or to convert to a compound, by chemical action (usually oxidation) the silver of an image. 3. (*n.*) a chemical reagent used for bleaching.

Bleeding of Color—The diffusing of dye or metallic tone away from an image.

Carbro—A process in which the differential insolubilization of the carbon tissue is produced by chemical reaction between the bromide print and the tissue.

Cinecolor—A subtractive two-color process. Prints are made on double-coated or single-coated film, from either bipack or any color-separation negative.

Chromatone—A color printing process which requires superimposing three collodion-gelatin layers whose images have been bleached and toned to the three subtractive colors.

Dufaycolor—A regular mosaic or reseau screen-film process for three-colored additive cinematography by either direct reversal or negative and positive technic.

Effective Wavelength—The effective wavelength of a screen is the wavelength that it is necessary to use in the radiation laws in order to calculate a ratio of radiation intensities equal to the ratio of the luminosities measured when one observes a black body through the screen at the two different temperatures.

Kodachrome—A color process brought out in 1935, for 16-mm. film, which uses an integral tri-pack developed by a reversal process involving color developers, whereby a subtractive positive original is produced.

Reseau—A geometric mosaic on photographic film, for the production of natural color-film.

Schultz Number—A number given to a dyestuff in the "Farbstofftabellen" of Schultz and Lehman, published by *Akademische Verlagsgesellschaft,* of Leipzig. (It should be noted that the numbers in the seventh edition (1931) are different from those in the previous six editions.)

Selective Dye Bleach—A process wherein a dye distributed uniformly in the emulsion layer is selectively discharged under the control of a photographic image.

Subtractive Primaries—The three printing colors used in a three-color subtractive process: magenta (minus-green), cyan (minus-red), and yellow (minus-blue).

IMPROVED RESOLUTION IN SOUND RECORDING AND PRINTING BY THE USE OF ULTRAVIOLET LIGHT*

G. L. DIMMICK**

Summary.—*The resolution of sound-film records has been increased by the use of ultraviolet light in recording and printing. Because of the absorption characteristics of the emulsion, exposures made by ultraviolet light are restricted to the surface. This reduces spreading of the image. The fogging of the track that usually results from halation and reflection from objects in the path of the light is almost entirely eliminated. Since the light-energy is restricted by means of a filter to a very narrow band, chromatic aberration of the lenses is reduced.*

The definition of the very fine recording light-beam is limited by diffraction. This limitation is materially decreased as a result of the decrease in wavelength of the radiant energy.

It is the object of this paper to discuss improvements in the resolution of photographic sound-film records by the use of ultraviolet light in printing and recording, and to point out the nature and magnitude of the resulting improvements in sound-record characteristics. The idea is not new, having been proposed previously by Oswald and others, but this is, to our best knowledge, the first practical application.

It will be instructive first to consider the nature of an ideal photographic sound recording system, and although the variable-width system is discussed here because the present improvements have been made in connection with the development of variable-width recording methods, the requirements of the variable-density system are very similar. Ideally, the photographic recording of sound is accomplished by imaging a uniform line of light, of infinitesimal width and of length varying with time, upon a uniformly moving photographic medium which develops black where, and only where, it has been exposed to the line of light.

While it is easy for the mind to conceive these ideal conditions, the real recordings must be made with physical apparatus upon a physical

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*Presented at the Spring, 1936, Meeting at Chicago, Ill.

**RCA Manufacturing Co., Inc., Camden, N. J.

medium, so that the real accomplishment of the result is beset with many difficulties and is brought about slowly through an extended process of development or growth.

The nature of the requirements of an ideal recording system clearly suggests that the whole matter is one of resolving power in the apparatus and of resolving power in the medium; that is to say, we must seek a means of producing an image of a slit that is of infinitesimal or extreme narrowness, which can be accomplished only by an optical system of high resolving power. Furthermore, we must have a medium that will record an impression of this image with perfect fidelity,

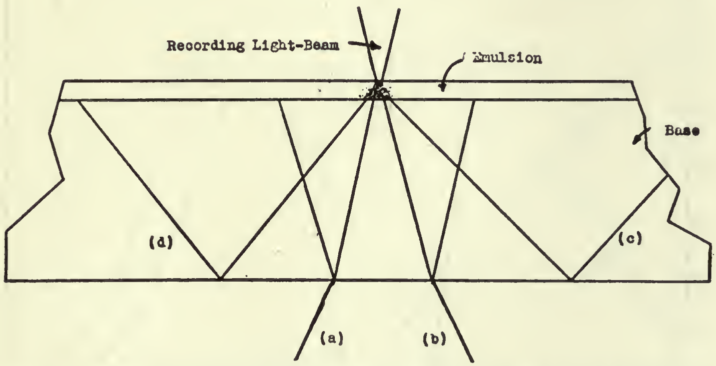


FIG. 1. Path of the recording light-beam through the emulsion and base of the film.

which means that the medium must also have a very high resolving power.

Continuous development of the variable-width recording system over a period of years had brought optical recording systems to such a state of perfection that, despite improvements in sound recording emulsions, very little improvement in record quality resulted from further increases in optical resolving power. This meant that the limit of record quality was set by the resolving power of the photographic emulsion, and that further improvements had to be sought in the direction of increasing this resolving power.

It had long been known that some day no further improvements would be possible without increased film resolution, but possibilities

of improvement in other directions continued to offer themselves for many years and were of sufficient importance to keep the matter of film resolution still in the background. Recently, methods of improving film resolution have received more serious consideration, and it is the solution of this problem that is the subject of this paper.

Let us consider first what occurs in the emulsion when recording in the conventional manner. The image of the recording slit has already been decreased in width to one-sixth of one mil to reduce the slit effect at high frequencies, but since the emulsion thickness is one-

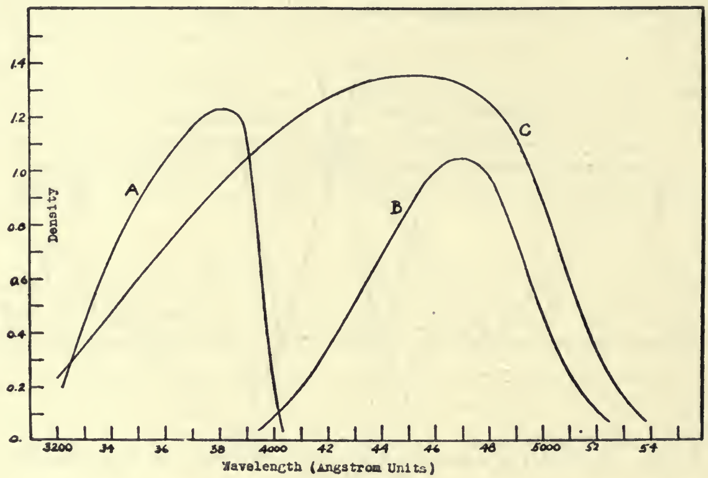


FIG. 2. (*A*) Transmission characteristic of recording filter; (*B*) transmission characteristic of emulsion; (*C*) sensitivity characteristic of commercial sound recording.

half mil, and the emulsion itself is a white translucent diffusing material, it is impossible to restrict the light within the emulsion to the dimensions of this slit image. The reason for this is made clear in Fig. 1, which shows a cross-section of the film and the recording light-beam drawn to scale. After the light enters the top layer of the film, it is immediately scattered, and exposes much of the silver outside the outlines of the light-beam. The intensity of the light-beam decreases as it penetrates the emulsion, because of absorption, but it still has considerable actinic value upon reaching the base of the film. Part of the light is then reflected back from the base, exposing the bottom side of the emulsion. Of the light that strikes the base at

less than the critical angle, only a small part is reflected; but the part that falls outside the critical angle suffers complete reflection, giving rise to halation. The light that is transmitted through the base must be completely absorbed by painting all the surfaces that it strikes, or the stray light will be increased by reflection from these surfaces.

All these objectionable sources of stray light can be eliminated and the resolution of the film greatly improved by restricting the luminous energy to a small band of frequencies that are strongly absorbed by the emulsion. This is accomplished by inserting a filter in the path of the light from the incandescent recording lamp or printing lamp,

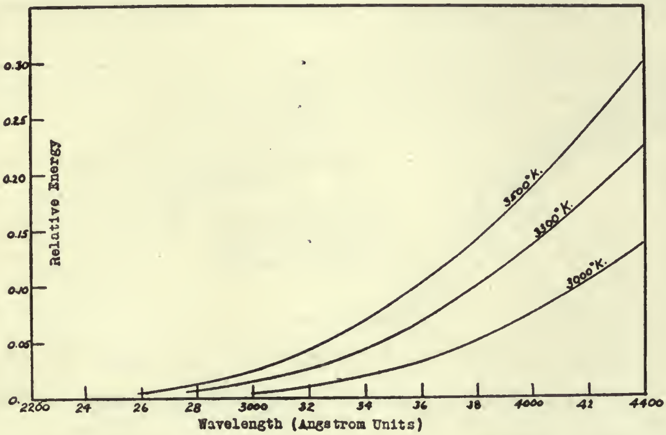


FIG. 3. Curves of relative energy from incandescent tungsten at various temperatures.

as the case may be. Curve *A*, Fig. 2, shows such a filter, transmitting freely in the band 3400 to 3950 Å. Curve *C* shows how the sensitivity of a commercial sound recording film varies with the wavelength. This is not a true film sensitivity curve, but shows the product of the energy from the incandescent lamp and the film sensitivity at any wavelength. It may be seen that energy of wavelengths from 3200 to 5200 Å. contributes materially to the resultant exposure. Curve *B* shows the transmission of the emulsion, and was obtained by placing two pieces of film with their emulsions in contact and exposing one through the other. It is interesting to note that the emulsion transmits very freely light of wavelengths longer than 4300 Å, but absorbs heavily at wavelengths less than 4000 Å. By restricting

the luminous energy to the small band of curve *A*, the emulsion becomes a strong absorption filter for all the light falling upon it, and two important results are accomplished. First, the exposure of the emulsion is restricted to the surface, because the energy is absorbed before it can penetrate very far; and, second, practically no energy passes through the emulsion, to be reflected and cause stray light. The first result is probably the more important. It is obvious that if it were possible to expose an extremely thin layer and obtain sufficient density, the resolution would be improved because there would be very little spreading of the image. For variable-width sound recording, it is necessary that the emulsion be sufficiently thick to produce a density of at least 1.5 when all the silver is exposed. Ordinary posi-

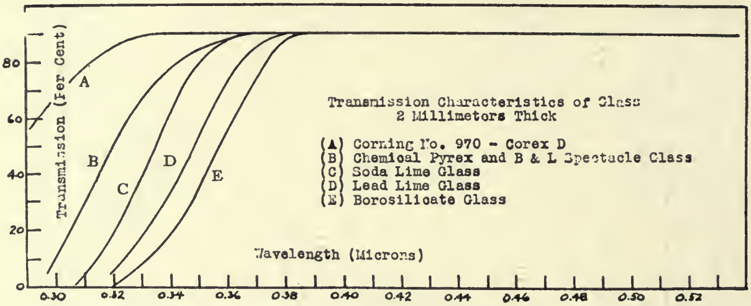


FIG. 4. Transmission characteristics of various types of glass, 2 millimeters thick.

tive emulsions have about three times this much silver, which excess serves to increase the speed and contrast at the expense of resolution. When a photographic emulsion is required to reproduce variations in brightness faithfully, as in the case of photography and variable-density sound recording, the proper contrast is most important; but for variable-width sound recording, contrast is relatively unimportant except so far as it improves the resolution.

The use of a restricted frequency band not only increases film resolution, as explained, but also improves the resolving power of the optical system, and consequently the definition of the image of the slit. This improvement is of a dual nature; first, losses in definition due to chromatic aberration are reduced by using a narrow band of radiations, and, second, the use of the short ultraviolet wavelengths reduces diffraction at the slit and improves optical resolving power. It

is well known that the resolving power of optical systems can be improved by shortening the wavelength of the light with which the object is illuminated, and important advances in microscope practice have been based upon this principle. Although in recording sound our optical system is the reverse of a microscope, producing a reduced image of a large object, its resolving power, and consequently image definition, depend in the same manner upon wavelength.

The narrow frequency band between 3400 and 3950 Å is ideally suited for sound recording, because radiations of this frequency can

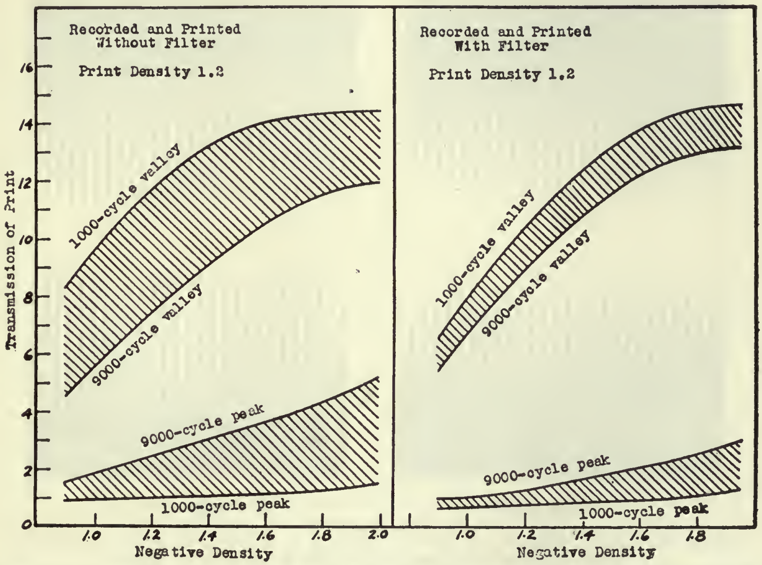


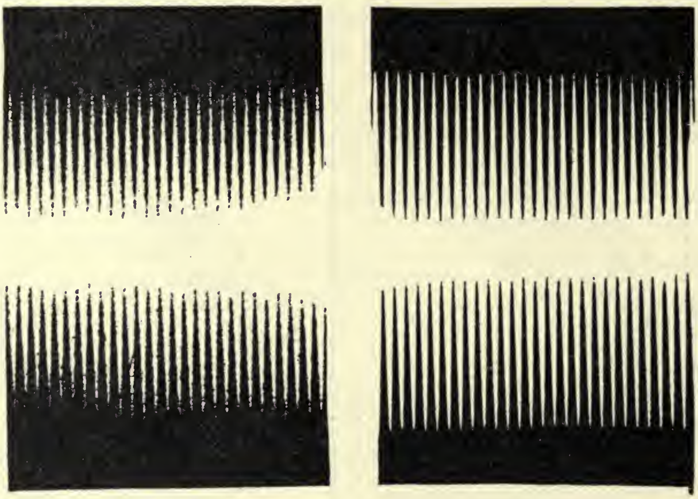
FIG. 5. Over-all effect of the ultraviolet method of recording and printing.

be obtained from an incandescent lamp and because ordinary flint glass, which is necessarily used in the corrected lenses, transmits this band. In other words, this band of wavelengths is attainable from an ordinary light-source, and can be transmitted through an ordinary optical system. Fig. 3 shows curves of the relative energy from incandescent tungsten at 3500, 3300, and 3000°K. The energy increases rapidly as the wavelength or the temperature is increased. Among other things, the life of an incandescent filament is a function of its temperature and the ratio of the surface area to the volume of the filament. A satisfactory compromise of lamp life and luminous

efficiency in the band 3400 to 3950 Å has been found in a lamp having a current rating of approximately $7^1/_2$ amperes.

The curves of Fig. 4 show the transmission of various types of glass having a thickness of 2 millimeters. The two achromatic lenses used in the recording optical system have a total of about 5 millimeters of flint glass. The condenser lenses are made of spectacle crown glass, which has much higher transmission at short wavelengths than flint glass.

The over-all effect of the improved method of recording and print-



White Light *Ultraviolet*

FIG. 6. Enlargements of sound records of 9000-cycle prints: (*left*) made with white light, (*right*) with ultraviolet light.

ing is shown in Fig. 5. The peak and valley transmissions of a 1000-cycle and a 9000-cycle print are plotted against negative density. The curves at the left show the effect of recording and printing with white light. Those on the right show the improved effect of recording and printing with ultraviolet light. The shaded portion represents the relative attenuation at 9000 cycles. It will be observed that the maximum response at 9000 cycles for white light is 55 per cent, and for ultraviolet light 78 per cent of the 1000-cycle value.

Attenuation of high frequencies is not the only manifestation of low resolution in sound records. Such attentuation arises from too little transmission through the print valleys, and too high transmission

through the print peaks. It is easily seen that if the excess of transmission through the peaks is not equal to the deficiency of transmission through the valleys, then at any given frequency the average transmission of the sound-track will not be equal to 50 per cent, and will be a function of the amplitude of the recorded wave. When this unbalanced condition occurs, sounds consisting of high frequencies whose amplitude varies at a lower frequency can not be reproduced without also reproducing the frequency of the amplitude variation. This gives rise to a spurious sound, which did not originally exist at

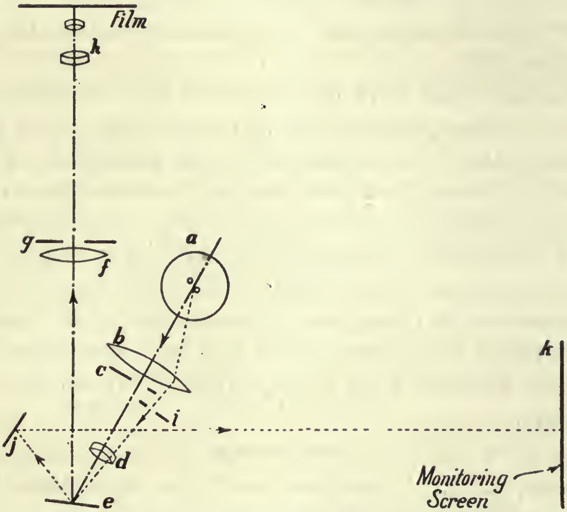


FIG. 7. Schematic diagram of Photophone recording optical system.

all and is especially noticeable in the sibilants and in metallic sounds such as the jingling of keys. Control of this effect and its complete elimination are achieved by properly balancing conditions of exposure and development. It can be seen that the peak and valley attenuations are equal over a much wider range of negative density in the case of ultraviolet recording and printing than in the case of white light recording and printing. Thus, the use of ultraviolet light increases the flexibility of the system which, in practice, is important because it relieves the demands upon the film processing laboratories.

Fig. 6 shows an enlarged view of a 9000-cycle print. *A* was made with white light for both the negative and print, and *B* was made with ultraviolet light for both negative and print.

Fig. 7 presents a schematic diagram of a Photophone recording optical system.[1] For recording with ultraviolet light, the ultraviolet filter is placed between the lamp *a* and the condenser *b*, to filter the light that passes through the recording aperture *c*. A red filter is placed before the monitoring aperture *i* so that the image upon the monitoring screen will be visible to the eye while at the same time the monitoring system can introduce no actinic stray light into the recorder. The objective that images the slit upon the film is achromatized for 3650 Å in the ultraviolet, and for the mercury green line so that the slit may be focused upon the film by removing the ultraviolet filter and observing the image through a Wratten series *62* mercury green filter.

The recordings that were demonstrated were noiseless push-pull ultraviolet recordings, printed with ultraviolet light on the RCA non-slip contact printer.[2] An experience in the production of the selections from *The Eternal Road* demonstrated the importance of printing high-quality recordings with a non-slip printer. The first prints were made on a commercial contact printer especially adapted to sound printing, and with ultraviolet light. The result was not acceptable to the composer or his colleagues. The non-slip printer was then obtained, and prints were made with it that were pronounced satisfactory by these persons, who, it goes without saying, are extremely critical judges.

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DISCUSSION

MR. FRANK, JR.: In order that you may understand the conditions under which the demonstration was given, the music was recorded as music for a legitimate stage production. The recording is supposed to take the place of the customary orchestra. No photograph, of course, was made of the orchestra when the record was made. You are supposed to experience the illusion of having the orchestra in the same auditorium with the production.

MR. WOLF: The question was raised, Mr. Batsel, as to the difference between the variable-width and variable-density recordings by this method.

MR. BATSEL: In Fig. 6, showing a variable-width sound-track, the light and dark areas are sharply defined. Usually there is a gradation in density, rather than sharp black and sharp white.

MR. RICHARDSON: Which type of recording is affected most by using the ultraviolet method?

MR. BATSEL: I should say that the effect is greatest in variable-width recording, because that type of recording depends upon image definition.

MR. JOY: What was the wattage of the light-source used? Is there any difficulty in getting the necessary amount of light through these filters?

MR. BATSEL: With a $^1/_6$-mil slit, we get a density of 1.8 on the negative through the filter, with our ordinary optical system, using a 10-volt, 7.5-ampere lamp. The filter was a Corning *584* ultraviolet filter.

MR. TASKER: Was the lamp current exactly 7.5?

MR. BATSEL: About 8.

MR. TASKER: What was the temperature?

MR. BATSEL: About 2100 Å.

MR. ROBERTS: As I understand it, you choose a band of wavelengths that are absorbed by the emulsion. Is the absorption a characteristic of the undeveloped film with high silver highlights or of the gelatin itself? Is it not a fact that if it were a characteristic of the gelatin you would not get enough light through to the print?

MR. BATSEL: It is a characteristic of the raw emulsion.

MR. WOLF: What proportion of the improvement in this recording is due to the printing and what due to the ultraviolet recording method?

MR. BATSEL: The improvement is due, as stated in the paper, to the fact that the light does not penetrate into the emulsion. The light in the band we are using is absorbed readily; the film is naturally a filter in itself.

MR. WOLF: The prints were not satisfactory before you improved the printer?

MR. BATSEL: No. Sprocket modulation, slippage, bad contacts, and things of that sort, put distortion into the print that was not in the negative. Referring to Fig. 6, the valleys would be filled in and the peaks wiped out, but not in a uniform manner. Consequently, there was distortion.

MR. WOLF: Do you regard the non-slip printer as really quite an improvement in the printing process? Could it be used for other types of film as well as for ultraviolet recorded film?

MR. BATSEL: Yes; for printing any sound-track.

MR. FRANK, JR.: It was recently announced at Hollywood, in connection with the non-slip printer, that anyone who is interested in manufacturing a non-slip printer using the RCA design features and patents can obtain a license to do so if he will communicate with us in Camden; and licenses so granted will not involve cost to the licensee.

MR. RICHARDSON: Would the affect of the ultraviolet light upon the film assure permanency at least equal to that attained now with white light? In other words, would the effect upon the silver possibly be as lasting as it is now, or more or less—that is, with equal care in fixing and washing?

MR. DEPUE: I have in my possession a film made in 1897. I washed it and developed it myself, and of course it was washed very thoroughly. That film today, so far as I can see, has not lost anything in quality. Perhaps it has a few specks in it, but to all intents and purposes, the film is exactly in the same condition it was in when I developed it in 1897—a black-and-white film, made outdoors. We did not have artificial light then. It is a 60-mm. film.

MR. MILI: The photographic deposit of silver in the case of recording sound with ultraviolet light is essentially a surface deposit, whereas in the case of re-

cording with white light it is a deposit of appreciable thickness, penetrating below the surface. If atmospheric conditions affect the film it is obvious that most of the change will occur at the surface, and that the sound-track obtained with ultraviolet light will suffer more than that obtained with white light. Again, any mechanical injury, such as scratching, would be more detrimental to the former than to the latter.

Mr. Kellogg:* Although a number of expressions of opinion have been given on the question whether films recorded by ultraviolet light might prove less permanent than those recorded by white light, and these opinions were all to the effect that such a danger was extremely remote, those who might have been in a position to speak with most authority were not at the meeting at the time. I feel that it will be desirable to offer enough further evidence to allay any fears of such a danger.

After the meeting I spoke to a number of members of the Society who are exceptionally well informed upon photographic materials. Without exception, they felt that such a danger was practically unthinkable. In the first place, the exposure to ultraviolet light in recording, which produces the image, is infinitesimal compared to the exposure to ultraviolet light to which practically all films are subjected in handling subsequently to development. Therefore, any such lack of permanence would have to be the result of some effect to which the film was susceptible prior to processing, and not subsequently. It is well known that prolonged exposure to ultraviolet light will cause film base to deteriorate, but the dosage of ultraviolet required to accomplish that is thousands or perhaps millions of times the dosage used in exposing the emulsion. The best evidence would be to examine spectrograms in which portions of the image are produced by ultraviolet and portions by white light.

Among others I talked to Dr. L. A. Jones, who was willing to be quoted as saying that no one need have the least misgivings as to the permanence of negatives made with ultraviolet light as compared with those made with visible light. He recalled spectrograms made years ago which are still in good condition.

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* Communicated.

PRIMARY CONSIDERATIONS IN THE DESIGN AND PRODUCTION OF THEATER AMPLIFIERS*

T. D. CUNNINGHAM**

Summary.—*Certain considerations in the design and production of theater amplifiers are of primary importance to the reliability and performance of the equipment in service. These comprise, in general, the choice of the component parts; the arrangement of the parts in the complete assembly; the construction of pre-production models for proving the design; and the care in the manufacture and final test of the product.*

Early types of theater amplifiers were for the most part designed and produced with limited knowledge of actual field operating conditions—the natural consequence of the birth of a new industry and the immediate need of that industry for amplifying equipment to fulfill its requirements. Besides the disadvantage of battery or motor-generator operation, the amplifiers were large and in some respects rather complicated to install and operate, owing to the fact that they were elaborately equipped with numerous meters, switches, and other controls. Nevertheless, looking back upon the performance of those amplifiers, we are forced to admit that for the greater part they did their job well, particularly when we consider the fact that they were produced on short notice for a new industry.

With the advent of complete a-c. operation, and with the increased knowledge of practical field operating conditions, the designs of sound motion picture amplifiers became somewhat simpler, with regard to installation and operation. Today the industry requires equipment that can be installed upon short notice and with a minimum of effort, and which embodies only the control features essential to proper operation. More important than that, the industry demands equipment that will perform to the complete satisfaction of the patrons, and will continue so to perform throughout its life with a minimum number of interruptions. With these requirements in view, in this paper will be outlined the primary considerations that

* Presented at the Fall, 1935, Meeting at Washington, D. C.
** RCA Manufacturing Co., Camden, N. J.

must be taken into account in the design and production of present-day theater amplifying equipment.

The first requirement in the design of a theater amplifier is a knowledge of the size and the general character of the theaters which it is to serve. From experience gained in the field, four general types or sizes of equipment have been found sufficient to serve the majority of the theaters, not only from the point of view of performance, but economy as well.

Practical methods have been established for predetermining the audio power required to attain good sound distribution with loud speakers of known characteristics, in auditoriums corresponding to the four general sizes of equipment. Experience in the field and in the laboratory has made it possible to know in advance the general effects of specific types of theaters upon the response of the system and the latitude of variation that must be allowed to compensate for those effects. To adapt the sound system more closely to varying types of theaters and films, the reproducing amplifier should be provided with means for regulating its frequency response to conform to the existing circumstances.

Knowing the power required for the loud speakers and the power delivered by the sound head with the average run of films, the designer is in a position to calculate the total amplification (including a reserve for compensating for varying modulation levels from film to film) required to realize the required output power. Many types of vacuum tubes are available for the amplifier circuits, each with its particular operating characteristics. The existence of so many types simplifies somewhat the problem for the design engineer; nevertheless, care and judgment must be used in selecting the type or types to be applied, in view of the requirements to be met in the design and operation of the equipment, and such factors as replacement cost, ease of obtaining replacement parts, and performance suitability must be considered. Characteristics such as freedom from microphonics, filament power consumption, and ability to produce the required gain or power output with minimum harmonic distortion are the bases of selection for performance suitability.

The lay-out of the circuit and determination of its constants follows the selection of the tubes. For the most part, the determination of the circuit constants, to provide the requisite amplification, frequency response, and audio output, is accomplished mathematically. Although such calculations may often be quite accurate, it is

always regarded good practice to check the circuit constants by means of a rough set-up in the laboratory. This procedure not only enables a preliminary check on the circuit operation, but in some instances uncovers undesirable features and suggests improvements.

No factor is more important in the design of theater amplifiers than that of selecting the principal component parts: transformers, reactors, capacitors, resistors, volume controls, switches, relays, *etc.* First of all the designer must have a knowledge of the conditions under which the equipment is to operate. He must know (*1*) whether or not the equipment is to be exploited in domestic, foreign, or both fields, and the extremes of temperature and humidity normally encountered in those areas; (*2*) the extreme daily cycle of operation to be anticipated; and (*3*) the type and variation of power supplied to operate the equipment. In addition, he must make proper allowance in his design for maximum working voltages and temperature rises. Since most sound equipment produced is subject to installation in either domestic or foreign fields, the component parts should be designed to operate reliably at a temperature at least 45 C° below ambient temperature, and a relative humidity of at least 90 per cent. Further, the parts must be designed to operate without failure for approximately 15 hours daily for several years, even though on the average the cycle of operation is appreciably less than that. In order to assure such reliable operation, high factors of safety must necessarily be allowed. In designing capacitors and transformers, in particular, although this applies equally well to other components, an accurate knowledge of the working voltages is necessary so that sufficient insulation may be provided against possible breakdowns. In the design of such parts as relays, volume controls, and switches, careful consideration must be given to the choice of the contact material and the action of the contacts, to assure quiet operation, particularly in high-amplification circuits. Assurance of the reliability of most of the parts may and should always be gained through life-tests in the laboratory, which may take the form of continuous application of abnormal voltages for many weeks to capacitors, transformers, and resistors; or the operation of switches, volume controls, and relays for many thousands of cycles or rotations under abnormal temperature and humidity, to simulate long periods of service.

Of primary importance in the assembly design of theater amplifiers is the consideration of mechanical strength and the possibility of

transporting the device to its destination without damage. No less important is the matter of the placement of the components with respect to each other to assure satisfactory electrical performance. This consideration is particularly important in a-c. operated amplifiers, which for the most part constitute present-day designs. The principal undesirable characteristics to be guarded against are (*a*) background noise, including hum, (*b*) microphonics, and (*c*) instability, in the form of regeneration or oscillation. The main sources of hum in an amplifier are the power transformer, the filter reactor, and the main filter capacitor, owing to the fields set up in and about them as a result of the high alternating components of the currents in them. Therefore to minimize the effects of these parts upon the rest of the circuit, the power transformer and the filter reactor in particular should be well shielded magnetically, and placed as far as possible from the input and interstage circuit components. Further advantage has been found in orienting the cores and coils of the transformers and reactor units so that their magnetic coupling with the audio input and interstage transformers is weakest. To reduce the hum further, the audio input and interstage transformers must be effectively magnetically shielded. As mentioned before, under the subject of tube selection, a low microphonic propensity is an important factor. In addition, however, further protection against microphonics must be provided by very flexibly cushioning at least the first two audio tube stages. The most effective cushioning is provided by sponge rubber or light steel spring mountings. The designer can do much to assure stability of operation by being careful to keep the input and output circuits as widely separated as possible. So far as practicable, that can best be done by placing the input and output terminal boards and wiring at opposite ends of the amplifier.

The design engineer is today giving the installation and service engineer and the projectionist more and more consideration in respect to the lay-out and design of theater equipment. More specifically, he has in mind to do everything practicable in the design to make it easier to install, operate, and service the equipment.

(*a*) *Installation Considerations.*—A theater amplifier, whether designed for rack or wall mounting, must be as small in size and light in weight consistent with good performance, in order that it may be handled as easily as possible during installation, and occupy an unobjectionable amount of space in the projection room. It has been found that the front-service type of rack or cabinet is most economi-

cal of space since it can be mounted directly against the wall of the projection room without the necessity of gaining access at the rear. Much advantage can be gained in selecting the size and number of conduit knockouts, and particularly their location, so as to permit making the installation with a minimum expenditure of labor and time. Provision should be readily available for adjusting the equipment to the nominal power supply voltage and to the frequency response characteristic most suitable to the theater.

(b) *Operation Considerations.*—The projectionist is quite occupied in most instances, in keeping the show going, and it is not fair to burden him with a number of unessential controls, the adjustment of which he must continually keep in mind. With that in mind, the designer has in recent years greatly simplified and reduced the number of controls on amplifier panels. To some persons, the older designs adorned with many meters and controls of various kinds seem to be impressive, but the important consideration in equipment of this nature is that it shall be simple to operate and permit the least chance of error upon the part of the operator. From that point of view it has been found desirable and convenient to be able to control the volume from a point in the auditorium as well as in the projection room. An attendant in the auditorium is, by virtue of his location, better able to judge the level of the sound, and to adjust it properly to the prevailing conditions. For that reason therefore, provision should be made in designing the equipment for the installation of a satisfactory remote volume control. The capacitor motor type with a control station in the auditorium has been found to perform quite satisfactorily in this respect.

(c) *Service Considerations.*—It may be safely said that no equipment has yet been made that had no operating difficulties, even though the greatest of care may have been exercised in designing and producing it. Notwithstanding the fact, the designer and producer of equipment must continue his efforts toward the realization of trouble-free operation. Until that goal has been attained, the service engineer and his problems must be given due consideration in the design and production of the equipment. In addition to his regular calls, the service engineer is subject to emergency calls, in view of which, particularly, the designer should give all consideration to the need of locating and correcting troubles in a minimum of time and with least effort. There must be constant appreciation of the service problem during the process of design, with particular reference to (*1*) the accessibility

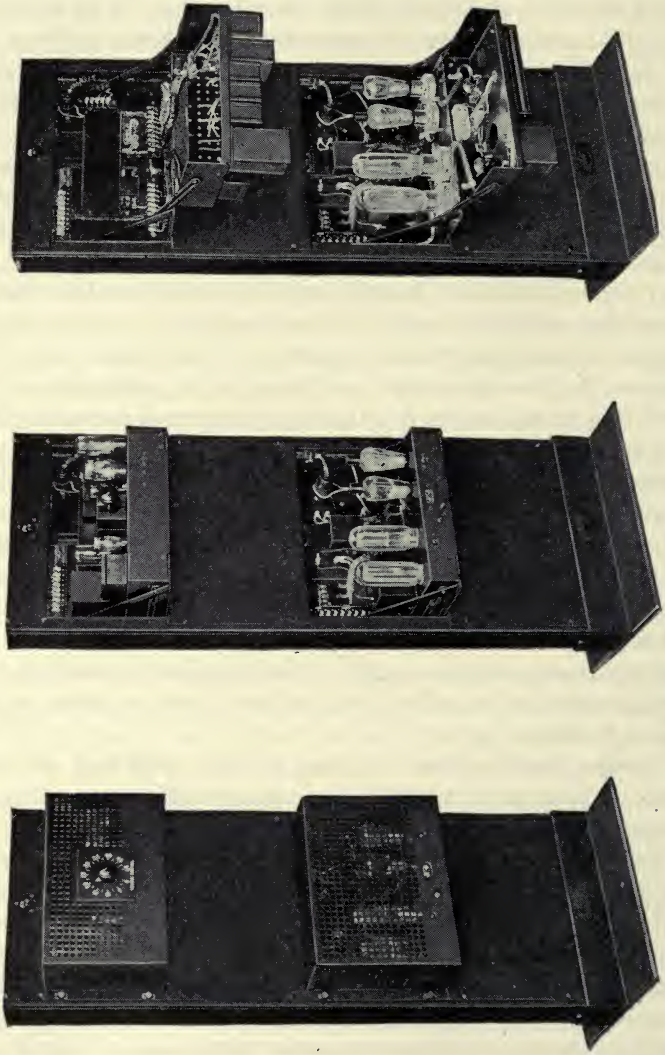

FIG. 1. Amplifier panel, illustrating the front-service form of construction.

of the parts; (*2*) the identification of the parts; (*3*) the judicious segregation of the parts most likely to give difficulty; and (*4*) the proper fusing of important branches of the circuit.

Without doubt the most important of these considerations is that of accessibility of the parts. The front-service form of construction obviously lends itself quite readily to servicing. The panel is mounted close to the wall, and there is no necessity of getting at the rear of it; as the result, the service engineer has ample space in which to work. Next is the matter of accessibility of the various sections of the panel and the component parts in those sections. A form of construction that has proved to be quite satisfactory from this pcint of view is shown in Fig. 1. Each amplifier comprises three principal parts; namely, a vertical panel, a base support, and a base proper. Upon the vertical panel are mounted the heavy power supply parts, such as the power transformers, filter reactors and capacitors, *etc.* Upon the base support are mounted a few parts, but its main function is that of supporting the main base and some of the inter-cabling. The main base supports most of the amplifier parts proper. When the amplifier is completely opened for inspection or service by means of the supporting hinges, a large majority of the parts and their connections are open to inspection or removal if necessary. The main amplifier base can be easily removed without the use of a soldering iron, and replaced or worked upon by itself. In its operating position, the base is folded back into the rack, and a perforated cover, fastened by easily removable thumb-screws, holds it in place as shown.

The component parts may, and preferably should, be marked so as to enable the service engineer to identify them readily. Parts such as capacitors, which are somewhat critical as to failure, should be kept segregated as much as possible from other components such as transformers and reactors. In portions of the circuit employing rather large capacitances, it is well to split the capacitances into several sections in parallel, so that if one section fails it can be quickly cut out of service with least interruption to the program. Important portions of the circuit should be fused against possible trouble. This applies not only to the primary circuit, but to some parts of the secondary circuits as well. For example, it is deemed wise to fuse the separate filter capacitor sections so that in the event of failure of a section the program may be permitted to continue until the end, when repairs can be suitably made.

Another consideration that must be constantly kept in mind during

the design of a theater amplifier is the fact that it must conform to the requirements of the National Board of Fire Underwriters. This is desirable, for several reasons: it is a form of insurance against damage by fire to either the equipment itself or its surroundings; it insures against unnecessary hazards to the lives of those working with the equipment; and adherence to the code of the Underwriters conduces to greater uniformity among the regulations of the municipalities of the country. In some respects, complete compliance with these regulations makes the job of the designer more difficult; but in the end, the effort expended is well worth while. Most important among the requirements are the use of materials throughout which will withstand the temperatures encountered in apparatus of this kind, the proper insulation of all current-carrying parts, and the protection of all primary and high secondary voltages against accidental contact.

The design completed, pre-production models should logically be made from the engineering drawings: (*1*) to establish definitely in the laboratory whether the device as designed fulfills its performance requirements; (*2*) to check the accuracy of the dimensions specified on the drawings; (*3*) to establish test limits for subsequent production units; and (*4*) to make available units for field tests, to assure suitability of performance and mechanical construction.

With the assurance of suitability of performance and mechanical construction, the engineering drawings may be released for quantity production. Particular care must be exercised by the inspectors in the Production Department to insure that all parts of the amplifier are produced in strict accordance with the engineering drawings, and that the permissible variations and tolerances are adhered to. Parts both made within the factory and purchased outside must be individually inspected and tested to determine proper compliance with the specifications before they are assembled into the amplifier. After completion of the assembly, the amplifier is ready for the final inspection and test. All mechanical points, including the inter-wiring of component parts, should be thoroughly inspected, and if not corrected should be made so before the beginning of final test. Final test of a theater amplifier should include:

(*1*) The measurements of all tube and other important operating voltages and currents.

(*2*) The determination of the frequency response characteristic at various volume control settings.

(*3*) The measurement of harmonic distortion in the power output stage at various output levels.

(*4*) The measurement of the over-all hum level.

(*5*) The establishment of whether the amplier is perfectly stable in operation at various volume control settings.

(*6*) The establishment of whether the microphonic characteristic is sufficiently low.

(*7*) The establishment of quietness of operation of the volume control throughout its range.

(*8*) The establishment of proper sound reproduction by actual listening test.

Theater amplifiers designed and produced in accordance with all the above-mentioned considerations should fulfill a very definite service in the industry. It is acknowledged that the cost consideration has not been mentioned. Cost is very important in the design and production of equipment of this type, but it should be treated as secondary in importance as compared to good and reliable operation.

The author wishes to acknowledge the contributions of J. N. Lehman and J. P. O'Neill in the design work in connection with the amplifier illustrated in Fig. 1 and described in the text.

CONTRIBUTIONS OF TELEPHONE RESEARCH TO SOUND PICTURES*

E. C. WENTE**

Summary.—*The principal elements of the sound system for motion pictures are: microphone, amplifiers, recorder, reproducer, and loud speaking receivers. The evolution of these devices began with the invention of the telephone by Bell. In this paper it is shown how subsequent studies relating to the telephone art contributed to their development prior to the advent of commercially successful sound pictures.*

The term 'sound picture' signifies a motion picture accompanied by sound which is reproduced from a synchronized record. It thus comprises two conjoined but distinct systems. Before the advent of sound pictures, silent motion pictures had enjoyed a long successful commercial history and had been brought to a high state of technical perfection. The sound system came as an adjunct, but has since become a *sine qua non* of the commercial motion picture.

The sound system used in connection with motion pictures is made up of a series of devices of which the following are the most essential: a microphone, with which sound is translated into corresponding electric current; a recording amplifier, with which the weak microphone current is transformed into a stronger corresponding current; a recorder, with which the time-pattern of the amplified current is translated into a permanently fixed corresponding space-pattern known as a sound record; a reproducer, with which the sound record is retranslated into electric current; a reproducing amplifier, the function of which is similar to that of the recording amplifier; and a loud speaker, with which the current from the reproducing amplifier is translated into sound. Although it is true that sound has been recorded and reproduced for many years without any electrical transformations, as in the Edison phonograph, it is unlikely that commercially successful sound pictures could ever have been produced by a system which did not have incorporated within it each of the above-mentioned devices. No sound picture system could succeed until each of them had been

* Presented at the Fall, 1935, Meeting at Washington, D. C.

** Bell Telephone Laboratories, Inc., New York, N. Y.

brought up to a certain standard of perfection, since the performance of the system as a whole is largely controlled by the limitations of the most imperfect of its several components. From the beginning of motion pictures, the addition of sound had been envisaged and various sound systems had been proposed by inventors from time to time. These inventors were ahead of their time, not because the public was unready to accept sound pictures, but because the various necessary elements were undeveloped. It was no more possible to build a successful sound system before these devices became available than it was possible for Leonardo da Vinci to succeed in his attempt to build an airplane before suitable engines were developed and the knowledge of aerodynamics had been extended. Fundamentally, the history of the sound system for motion pictures resides in the history of each of these constituent elements, for the development of which no single individual or group of individuals was wholly responsible. The impetus for their initial development came for the most part from outside the motion picture field.

The history of the microphone goes back to Alexander Graham Bell, who in 1875 first produced a device whereby sound was successfully translated into corresponding electric current. Not only was this invention epoch-making in electrical communication, but it also was the first step on the way leading to a sound system for motion pictures. Bell's extraordinary achievement can be thoroughly appreciated only by one who knows something of the complexity of speech waves and the minuteness of the powers involved. All the two billion persons in this world talking at once would not generate enough power to propel a modern automobile along a smooth road at a speed exceeding the legal limit, yet the microphone of a telephone system must operate with but a part of the power of a single voice. More remarkable still is the fact that in translating this power we must preserve the original wave-form.

The next advance in microphones came with the development of the carbon button, to which Berliner, Hughes, Edison, Blake, and others contributed. While the carbon button is not used in sound picture apparatus, it is of interest to us in that it is the first practical embodiment of the principle of amplification, for with it the power imparted to a diaphragm by sound waves is translated into a greater amount of corresponding electrical power. The carbon microphone is eminently suited for commercial telephony. It has exclusively held this field throughout the world over a span of several generations. It

is doubtful whether it will ever be displaced in this type of service. By a sacrifice in efficiency it can be designed so as to be relatively free from distortion. Such instruments have been widely used in radio broadcasting and public address systems, but even a high-quality carbon microphone is unsuitable for sound picture recording. With the distant pick-up conditions that here generally prevail, the sound intensity reaching the microphone is considerably less than it is in commercial telephony. With the high amplification that is required under these circumstances, carbon noise will intrude upon the signal to an intolerable extent.

The microphone which was able to meet the requirements for sound picture recording was originally developed, not for any commercial purpose, but as a laboratory tool for use in a program of research on speech and hearing, initiated by the late Dr. H. D. Arnold and carried out under the direct supervision of Dr. H. Fletcher and the late Dr. I. B. Crandall. Further objectives in the design of this instrument were to provide a means for measuring the performance of telephone instruments and to set up a standard microphone for reference purposes. This microphone was of the condenser type. It was described in the *Physical Review* in 1917 under the title, "A Condenser Transmitter as a Uniformly Sensitive Instrument for the Absolute Measurement of Sound Intensity." In this article the possible use of the instrument for recording sound upon photographic film was mentioned, although primarily with reference to the study of speech sounds. In much the same form as there described it was later used in recording sound pictures. The principle of the condenser microphone was not new. It had been suggested as early as 1881, but was wholly impracticable until electric current amplifiers became available. It is perhaps in principle the simplest of all types of microphones, as it comprises merely a pair of plates, one of which is fixed and the other movable under the action of sound-waves. It was thought originally that its performance could therefore be computed from its dimensions, if the movable plate were made in the form of a diaphragm. The motion of a free diaphragm under the action of an alternating force could be accurately determined by formulas derived by previous investigators. However, the actual performance of the instrument was found to depart greatly from that which had been computed theoretically. It was discovered that the thin layer of air between the diaphragm and the fixed plate had a profound influence upon the motion of the diaphragm. Means had therefore to be found

for calibrating the instrument. For this purpose a special form of thermophone was devised. Although it was disconcerting to find that the microphone performed otherwise than was expected, investigation showed that a proper proportioning of the air-film between the two condenser plates afforded an effective means for controlling the motion of the diaphragm, and hence the response *vs.* frequency characteristic of the instrument. The theory of this control was developed by Dr. Crandall. By a change in the dimensions of the film of air and by the substitution of a duralumin for a steel diaphragm in 1923, a condenser microphone was produced which had a sensitivity 100 times as great as that of previous models. This microphone was sufficiently sensitive to permit the pick-up of ordinary sounds at a distance without interference from noise voltages generated in the amplifier, whereas the use of the older models under such circumstances would have been impracticable. In various forms the condenser microphone was extensively used in laboratory investigation for almost a decade before the advent of sound pictures, and had been employed for some time in public address and radio broadcasting systems.

It has already been pointed out that, because of the low translating efficiency of a condenser microphone, it became a useful instrument only after telephone current amplifiers had been made available. Several practical types of amplifiers were developed for long-distance telephony, but today amplification of audio-frequency currents is almost universally effected by amplifiers of the vacuum tube type. The basic element of these amplifiers is the vacuum tube, which was developed from the three-electrode *audion* invented by Dr. L. De Forest. Vacuum tubes and amplifier circuits were developed and improved in the laboratories of the Western Electric Company so that vacuum tube amplifiers suitable for telephone service could be manufactured and installed in a transcontinental telephone line in 1914. In the following year commercial telephone service was inaugurated between the east and west coasts of our country. Subsequent improvements, not only in vacuum tubes but in circuits and in circuit elements, were made at a number of industrial research laboratories. Amplifiers of low distortion and increased power-carrying capacity, which have played an important role in sound pictures, were used not only in experimental laboratories but in communication and public address systems and in radio broadcasting some time before the commercial introduction of sound pictures.

The recorder used for recording sound upon photographic film appears to be a device of unique importance to sound pictures. This is possibly true as regards the modulated lamps used by Case, De Forest, and others, but not of the oscillograph as first used for variable-width recording nor of the light-valve for variable-density recording. The oscillograph was invented by Duddell as a means for studying the wave-form of alternating currents. The light-valve was devised for use in connection with research studies of the physical characteristics of speech and music. The chief objectives in the design of the light-valve were to obtain a mechanical structure which should be stable, respond uniformly throughout the frequency range of interest in music, operate with a relatively small amount of power, be capable of fully modulating in a linear manner the light reaching a film, and transmit enough light to the film to give the photographic emulsion a normal exposure. However, these objectives would have been without purpose if photographic films of great uniformity, and scientific information on processing methods, had not been made available by the manufacturers of photographic materials for motion pictures. To them the sound engineer is greatly indebted. The light-valve was used in the laboratories of the Western Electric Company for recording sound upon motion picture film in 1923, and for the commercial transmission of pictures over telephone lines in 1924, several years before sound pictures made by the Western Electric Company's equipment were first publicly shown.

In order to test their fidelity, the sound records made in the laboratories were reproduced with a photoelectric cell. This was a very simple matter, as suitable photoelectric cells had been available for some time. One of these cells was merely substituted for the condenser microphone in the recording amplifier, without any other alterations in the circuit.

The last in the sequence of essential elements of the sound system is the loud speaker. This also dates from Alexander Graham Bell. In his early demonstrations of the telephone receiver he used it as a loud speaker, although the loudness was insufficient to permit more than three or four persons, while grouped about the receiver, to hear the received sound. During the succeeding years numerous patents relating to loud speakers were issued.

Studies at Bell Telephone Laboratories of the characteristics of speech and telephone quality were being conducted by means of head receivers, which were quite satisfactory for the purpose. However,

the American Telephone and Telegraph Company was called upon to deal with the transmission of music as well as speech. The Laboratories therefore undertook the problem of studying music in a way similar to that in which speech was being studied. In 1924 a moving-coil loud speaker having a direct-radiating diaphragm was used in these studies. This loud speaker was designed with no commercial application in view but with the idea of obtaining an instrument which would operate without introducing an appreciable amount of distortion. Unfortunately, it had a rather small output power capacity. Studies in hearing, which were carried on at the Laboratories at this time, showed that the quality of music depended upon the level at which it was reproduced. For the study of music, therefore, a loud speaker was required that was capable of reproducing music at its original loudness level. To satisfy this requirement a special loud speaker of the horn type with a moving-coil drive was developed. This loud speaker, as regards quality, sound output capacity and efficiency, was superior to those previously available. It was designed and built purely for laboratory purposes. It was some time later that this loud speaker was brought out in commercial form by the Western Electric Company and used in the first public demonstration of its sound picture system.

All the essential elements of the sound system as adopted by the Western Electric Company were now available, at least in laboratory form. All, with the exception of the amplifiers, had come into being as instruments for use in laboratory studies of telephone problems. They would be here even if we had no sound pictures today. It was necessary only that these elements be brought together in proper commercial form and the system synchronized for the silent picture to become articulate. That event had now become almost inevitable.

It is not our purpose in this paper to discuss the subsequent commercial history of sound pictures, which in its broad outlines is familiar to the reader. Its commercial success was due to numerous important contributions, many of them made by forgotten men who, working with ingenuity and force, have brought the sound picture to its present high state of development. In the laboratory it is possible to get along with equipment which functions properly most of the time, but in commercial use failure to function is costly in its consequences. Great credit therefore belongs to the men who transformed the laboratory apparatus into successful commercial equip-

ment, and also to the men whose duty it is to see that the equipment is kept in operation, often under the most trying circumstances.

Such rapid technical progress has been made in the few years which have elapsed since the introduction of sound pictures that the early equipment and methods already seem antiquated. Some of the instruments which have here been described are becoming obsolete. It is not likely, however, that a sound system will ever be used in sound pictures which does not comprise the sequence of elements here enumerated, although the form of the individual devices may undergo important changes from time to time.

NEW HIGH-VACUUM CATHODE RAY TUBES FOR RECORDING SOUND*

M. VON ARDENNE**

Summary.—*In Germany the cathode ray tube has assumed a definite though not very important role in the field of sound reproduction, and in television it has become of such importance that mechanical methods of scanning are rarely considered nowadays.*

The paper describes a new high-vacuum cathode ray tube especially designed for recording sound, the purpose of the development being to avoid the disadvantages inherent in such tubes currently used. The fluorescent line required for recording is produced by means of an electroöptical system in which a controlled accelerating voltage in the path of the electrons from the cathode constitutes the "lens electrode" and achieves the focusing action. The characteristics of the tube are described in detail.

Technical development in various countries can be helped or hindered by the influence of the patent situation. The final decision as to whether a certain technical advancement is useful or not is in no way influenced by the patent situation, and depends only upon the intrinsic value of the advancement.

Under the influence of the situation peculiar to Germany regarding patents in the field of sound reproduction, the cathode ray tube has assumed a definite though not very important role. On the other hand, the cathode ray tube has become of such importance in solving problems in the field of television that mechanical methods are scarcely considered nowadays. Because of the intensive work that has been done with cathode ray tubes in connection with television, many fundamental advances have been made, and the technical value of using this method for recording sound upon film has been enhanced greatly.

Until the present time cathode ray tubes, especially those filled with gas, have possessed the following disadvantages:

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* Received March, 1935.

** Berlin, Germany.

(*1*) The properties of the tubes are not constant with time. Usually the effective light intensity decreases with the time that the tube is in operation.

(*2*) The life of the tube is rather short, due to the bombardment of the cathode by positive ions.

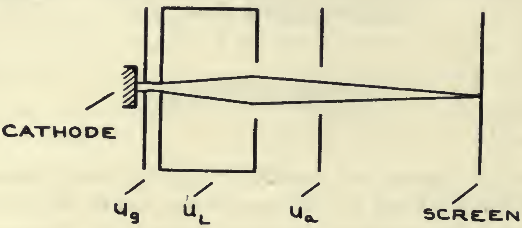

FIG. 1. The electroöptical path in the new high-vacuum tube.

(*3*) High-frequency deflections of the light-beam are usually produced partially in combination with special magnetic fields.

(*4*) The fluorescent spot or line is not free from parasitic disturbance by the control device.

(*5*) For distortionless reproduction the tubes can not be heated with alternating current.

(*6*) As is the case with other kinds of recording apparatus, the light intensity is often too low.

With the new form of tube construction to be described, the above-mentioned disadvantages are eliminated. The new tubes have been developed for recording sound with the benefit of experience gained in designing and constructing television tubes.

FIG. 2. Line-sound-film tube with combined variable-intensity and variable-amplitude characteristic.

With respect to establishing the path of the rays and the applications of "electrostatic" optics, the aspects are the same as described in the above-mentioned work. The main difference between the tube that is used in television and the one that is used for recording sound is

that in the latter case it is desired to have a fluorescent *line* whose intensity can be controlled, rather than a *spot*. This result can be attained by means of "electroöptical" cylindrical lenses, and with such an arrangement the same configuration for the concentrating and accelerating fields will exist for all electrons that are emitted from the cathode. Small differences in this configuration are enough to cause large differences in the distribution of light on the fluorescent line.

FIG. 3. Line-sound-film tube (normal product) with two cylindrical lenses in the electroöptical system.

Another difference in comparison with the tubes used in television is that no scanning is necessary, and therefore the fluorescent screen can be very close to the ray-producing system. The maximum attainable light intensity at a spot is much greater as a result of this smaller distance, and is dependent upon the saturation and fatigue characteristics of the fluorescent screen.

A complete discussion of the "electroöptical" system, the influence of the space-charge upon the line width, and the determination of the proper point upon the cathode emission characteristic curve at which to work, will not be given here. It will be sufficient to describe the most important properties of the completed tube; and only so far as they apply to recording sound upon film.

The "electroöptical" path is shown in Fig. 1. The electrons, emitted from the indirectly heated oxide-coated cathode, are propelled under the influence of the accelerating field produced by the positive voltage U_L of several hundred volts. This accelerating field will be more or less offset by the negative bias voltage U_g of the light-control electrode. This electrode works exactly in the manner

of the negatively biased control-grid of a modern amplifier tube. The control-grid does not take any appreciable energy. The "focusing action" of the first accelerating field always remains so strong that the divergence of the electron beam after passing the first ac-

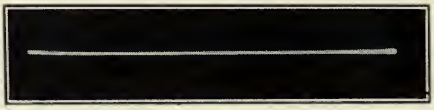

FIG. 4. Unretouched photograph of the fluorescent screen, showing the sharpness of the line and uniform intensity of illumination of the tube of Fig. 3.

celerating field will not be so large that the electrons will pass directly to the electrodes of the second accelerating field. The second accelerating field is built up between the main anode and the so-called "lens-electrode" by the difference between the anode voltage U_a and the lens voltage U_L. It works principally as a concentrating lens. For a given anode voltage there will be a value of lens voltage that will produce a sharp spot (or line) upon the fluorescent screen.

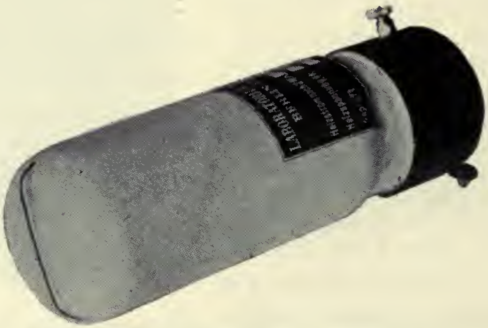

FIG. 5. Photograph of the complete tube.

A tube similar to the one represented diagrammatically in Fig. 1, is shown in Fig. 2. With this tube, in addition to the light intensity modulation, there is a corresponding change in length of the fluorescent line. The length of the fluorescent line, or the recording amplitude, becomes small when the control voltage is adjusted to produce a less intense line of light, and thus the changes in amplitude and intensity aid one another.

For a pure "intensity-control" the author has developed the system shown in Fig. 3. In this form the tube has scarcely any resemblance to the common cathode ray tube, but is much more like the typical amplifier tubes employing cylindrical electrodes. In this case, however, due to the higher voltages employed, greater distances between the electrodes are necessary. Because of the cylindrical arrangement of the electrodes, all electrons coming from the cathode are concentrated and accelerated to the same extent. The methods of supporting the electrodes insure a good symmetrical system and one that will remain in condition after use. The constant intensity of illumination and width of the fluorescent line are shown in the unretouched photograph of Fig. 4. Under the influence of the control voltage, the intensity of illumination varies equally along the entire line, while the width remains practically unaltered. The fluorescent line has a width of less than 0.5 mm. and a length of 4 cm., and can be made to assume other dimensions if desired. The position of the line is entirely free from disturbance by the control device.

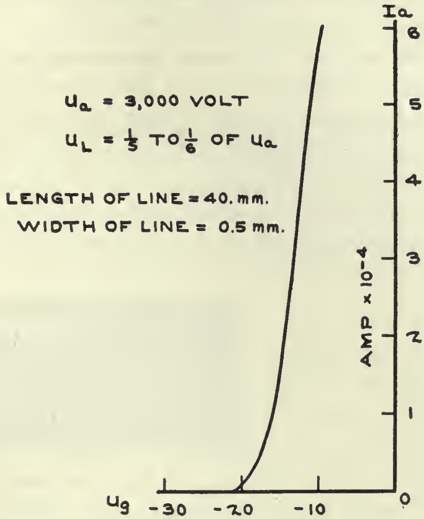

FIG. 6. Characteristic curve of the tube of Fig. 3.

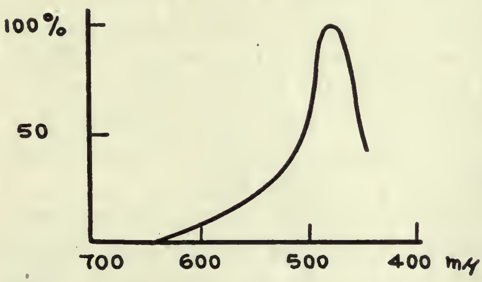

FIG. 7. Spectral distribution of intensity of the fluorescent screen (absolute).

As a result of experience gained in constructing television tubes it is possible to design for greater or lesser amplitudes. In addition, the position of the fluorescent line is not influenced by using alternat-

ing current on the indirectly heated cathode. The various slits that cause the lens effect are plainly shown in Fig. 3. The dimensions of the tube differ greatly from those of the older types of tubes, as shown in Fig. 5. When the working voltage is once attained there is no need of making additional changes. In this respect the analogy between this tube and the common amplifier is quite clear. As a high-vacuum tube the life is scarcely any shorter than that of an incandescent lamp or amplifier tube. With the old tubes a voltage swing of 20 to 50 volts was necessary; whereas, with this new type, 10 volts is enough to produce light to dark modulation. The characteristic curve of the tube shown in Fig. 3 is given in Fig. 6. The spectral distribution of intensity for the normal calcium tungstate

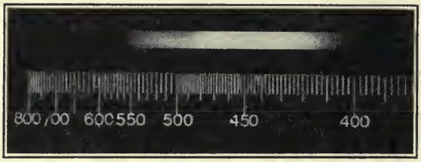

Fig. 8. Spectrum of the calcium tungstate screen.

screen is shown in Fig. 7, and a photograph taken on a super-pan plate of this spectrum is given in Fig. 8.

The light intensity is sufficient to allow photographs to be made directly upon positive film. In addition, it is possible to achieve still greater light intensities with an increase in anode potential without the disadvantages heretofore encountered. Larger anode currents can be obtained by changing the dimensions of the system. It should be noted that for the same anode current, a high-vacuum tube will produce a much greater light intensity than one of the older gas-filled tubes. In the latter case, a large percentage of the electrons does not reach the screen due to the scattering effect.

The plate input, in the tube here described, is less than one watt, under normal operation, which is less than the input to other devices used in recording sound, such as Kerr cells, glow lamps, *etc.* With such a small input it is possible to produce this voltage by means of small apparatus, having protective resistances for reducing the danger of the high voltage. The control power is also considerably less than that commonly necessary. The system is entirely independent of frequency in the region of medium and high frequencies.

AN EXPERIMENTAL PROGRAM IN VISUAL EDUCATION*

F. H. CONANT**

Summary.—*A discussion of experimental work now being carried on at the Massachusetts Institute of Technology on a program of visual education designed to facilitate teaching in the fields of science and engineering. The use of animation and the technic of its application in the first of a series of films showing the behavior of an electrical wave travelling along a 250-mile power transmission line, are described. Other films are considered and the possibilities of animation in other fields of technical training are indicated.*

Early last year the Massachusetts Institute of Technology began an experimental program to investigate the value of motion pictures as an aid in teaching some of the more difficult subjects in science and engineering. The first step in this undertaking was to obtain from members of the instructing staff (*1*) a broad concept of the field to be covered, (*2*) suggestions for specific subjects, and (*3*) methods of presentation designed to give the maximum assistance in teaching students in various stages of technical training.

A representative group of members of the faculty was asked to determine whether the proposed films should be silent or sound productions. The decision favored silent films with adequate explanatory titles, on the ground that teachers would have greater latitude in interpreting the subject. It was decided, however, that all films should be made with sound aperture, thus permitting the addition of a sound-track if such seemed desirable in the future. The production of silent films aided in keeping costs within the limits of a modest budget and assured a certain flexibility by permitting changes or additions from time to time. Among the many subjects suggested were such interesting possibilities as the operation of complex machinery, principles of physics, problems of human relations, time studies, and mathematical problems.

One of the most interesting objectives of the program was to investigate the possibilities of animation as a means of teaching

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* Presented at the Fall, 1935, Meeting at Washington, D. C.

** Massachusetts Institute of Technology, Cambridge, Mass.

subjects that often are difficult for students to visualize. Such subjects, or individual problems in some instances, lie not only in the field of undergraduate education, but in the advanced work of graduate students.

Having laid the groundwork for the program, the task of film production was made the responsibility of the Institute's Photographic Service under the direction of the author. In planning technical procedure and in adapting the subjects to scenario form he has had the very valuable coöperation of Professor A. C. Hardy of the Department of Physics, and Mr. F. Ramsdell of the Worcester Film Corporation.

The first production was an animated film in the field of electrical phenomena. The subject, *Traveling Waves on Transmission Lines*, was chosen because travelling waves undergo a variation with *distance* as well as with *time*, a characteristic that made them difficult to visualize and therefore encouraged the attempt to produce the phenomena in animated form. The film is a combination of scenes photographed in the field and animation showing the behavior of a wave on a 250-mile transmission line with open end. The production was based upon a laboratory study made by Professor L. F. Woodruff of the Department of Electrical Engineering, and was designed to be one of a series of thirteen films presenting complex electrical phenomena in animated form. The success of the first film led to the production of the second and third of the series, dealing with *voltage* waves on a short-circuited line.

The technic of animation developed by Professor Woodruff may be of some interest, for it entailed the problem of translating complex phenomena to a visual form readily understood by advanced students in electrical engineering. Since mathematical analysis has not yet reached the degree of development whereby travelling wave distributions may be calculated accurately, they were determined experimentally on an artificial line in the Institute's dynamo laboratory. A cathode-ray oscillograph control circuit was designed by Professor Woodruff, by means of which a succession of identical transients was produced, and curves of the sending-end voltage and the voltage at another point of the line were thrown upon the screen of the oscillograph. Oscillograms were made at each section (32 sections form a 250-mile line), and from enlargements of these oscillograms was plotted the wave distribution at intervals of an eighth of the line. An assistant then made celluloid templates to match the curves thus laid out.

The next step was to cut silhouette forms of the waves from medium-tone paper, and to interpolate between these laid-out curves to produce additional intermediate curves. In some parts of the travel, where sudden changes of shape took place, it was necessary to lay out each curve individually.

The electrical wave films were photographed upon a standard animation stand, lent to the Institute's photographic service by the Eastman Kodak Company. A drawing-board was fitted with registration pins identical to those on the platen of the animation stand, and sheets of white paper 9 × 12 inches in size were punched to fit the pins. A celluloid template with a rectangular cut-out and registration holes was placed over each sheet, and lines were drawn to indicate the bottom and left edge of the silhouette wave-forms. These forms were then pasted upon the paper sheets. The background of line, voltage scale, and generator were drawn upon another master template. Each wave-form was photographed through this template, which produced a uniform background in which the only animation was the closing of a switch, titles, and the change in wave-form as the wave moved along the transmission line. For the first three trips along the line it was found necessary to use 128 diagrams per transversal. Since the action dies down considerably from that point on, 64 diagrams, using two frames per diagram, were satisfactory for the remainder of the film. When projected in our lecture halls the scale is approximately half an inch to the mile, and the time reduction for producing the travelling wave in animation is of the order of 7500 to 1. A total of nearly 1500 silhouette wave-forms was used for each film.

In addition to the electrical films, the Institute has produced another, entitled *The Graphic Representation of Machine Operations.* This film, which opens with detailed views of a machine drawing, and then shows the various machining operations necessary to produce the parts shown in the drawing, is of an elementary nature. It was designed as an introduction to an animated film on descriptive geometry, which we hope to produce for the purpose of assisting first-year students to visualize three-dimensional concepts.

Although these films were produced for instructional purposes at the Institute, they are also available for loan to other educational institutions and to professional groups who may be interested in seeing them.

IS THE FEDERAL GOVERNMENT INTERESTED IN EDUCATIONAL FILMS?*

C. M. KOON**

Summary.—*A review of the film activities of various Federal agencies is presented, their educational significance suggested, and some general observations are made as to the Federal Government's interest in educational films. In conclusion, the vast potentialities of the educational film field are discussed and the part the Federal Government might play in its development pointed out.*

If one were to judge the Government's interest in educational films by Federal laws on the subject, he would be forced to consider that there was no interest. A more careful consideration of Government activities, however, reveals that the United States signed the *Geneva Convention to Facilitate the International Exchange of Educational Films* by agreeing to admit such films free of duty. It also sent an official delegation to the International Congress on Educational Cinematography which was held at Rome in April, 1934. When approached personally, some high Government officials have indicated a very definite interest in the use of motion pictures for instructional purposes, but this interest has not found expression in a centralized motion picture service.

Therefore, one must turn to the various bureaus and Federal agencies and study their motion picture activities as a means of determining their interest in educational films. At least fifteen agencies in the Federal Government make, distribute, use, or publicize motion pictures as part of their regular functions. The film work lies mainly in the field of service to the farmer, the teacher, the CCC camp educational adviser, and the motion picture producer who wants to sell his films abroad.

By far the most extensive motion picture services of any of the Federal departments are carried on by the War and Navy Departments, principally for entertainment and training purposes, and by the Interior and Agriculture Departments, principally for

* Presented at the Fall, 1935, Meeting at Washington, D. C.

** U. S. Department of the Interior, Office of Education, Washington, D. C.

instructional purposes. As a rule, Government films are available to responsible groups without cost, excepting transportation charges. The motion picture production and distribution activities of the various Federal agencies will be considered individually.

A small but well equipped motion picture studio, laboratory, and office are maintained by the Department of Agriculture. The service is unique inasmuch as it was the first organized effort upon the part of the Government to use motion pictures for instructional purposes. It is unique also because it is the only institution of its kind exclusively devoted to the production and distribution of instructional pictures on agriculture, forestry, conservation, rural engineering, and home economics.

Films produced illustrate how to raise and care for cattle, horses, swine, sheep, and poultry; how to produce crops of all kinds, combat injurious insects and diseases of livestock and plants; cope with engineering problems on the farm; build roads and trails; and how to care for the home and the family. They inform as to Federal regulations concerning animals, forests, crops, insects, rural engineering, and marketing. They convey to the public in general, and to rural dwellers in particular, the information and discoveries emanating from the scientific investigations of the Department of Agriculture.

The Department's film library numbers about 300 subjects, of which some 4000 copies are being distributed by the Department. At least an equal number of copies have been purchased by organizations and state, federal, and foreign governmental agencies interested in disseminating the information contained in the films. No record is available of the extent of the distribution of these purchased copies. However, since they are selected subjects, the circulation probably is greater than that of the films distributed by the Department. During the fiscal year 1934–35, actual reported attendance totalled about 2,115,000 for about 75 per cent of the borrowers.

Designed to aid in the work of extension and field workers, the primary use of the Department's films is by or under the supervision of such workers. However, loans are made to farmers' organizations, schools, colleges, churches, theaters, and other agencies or persons whenever copies of the desired pictures are available. The supply of copies, however, is not nearly large enough to meet such demands, and hundreds of requests have to be turned down annually.

The film activities of the Department of the Interior are not centralized as they are in the Department of Agriculture, but are carried

on by various bureaus within the Department.* The Bureau of Mines and the National Park Service are the most active.

The United States Bureau of Mines of the Department of the Interior has in its library of motion picture films approximately 3000 reels of silent pictures. These pictures are produced in coöperation with members of the minerals and allied industries for the purpose of disseminating information about mining methods and practices. Numerous subjects pertaining to principles of safety and first-aid are used for training purposes.

During the fiscal year the Bureau's films were shown on 61,010 occasions to an attendance of approximately 5,000,000 persons. The figures given above represent an increase of 23 per cent over the preceding year, and it is estimated that an even larger increase will take place during the coming year. About four-fifths of the requests at the present time are for the 16-mm. size.

The Bureau does not engage a production staff, nor does it do any laboratory work whatever. All expenses incidental to the production of these films and prints are paid by industries and their associations.

Letters and words of commendation regarding the inestimable value of these films for purely educational purposes have been received from. universities, high schools, and elementary schools throughout the country. The demand for the Bureau's films at this time far exceeds the available supply.

For many years the National Park Service has taken films of the parks, to record their natural beauties and encourage travel. Last year this service underwent considerable expansion by undertaking to circulate educational films in the CCC camps located in state or national parks. About 300 subjects were obtained from various sources mostly outside the Government, and an excellent service was rendered to the camps, causing an increased demand for the establishment of a centralized film service for all the camps. In addition to this distribution service, National Park Service cameramen have filmed the activities of the various camps themselves, showing the types of work that have been undertaken and the methods of training the enrolled personnel. About 30 reels have been completed and are available on usual Government terms. The Park Service also has coöperated with the University of Chicago and with Erpi Picture

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* A central Motion Picture Division has been established in the Department of the Interior since this article was written.

Consultants, Inc., in making six sound subjects on physical geology which are intended for instructional purposes and which may be obtained from a number of agencies.

The Bureau of Reclamation has a number of silent films in circulation. These films show the engineering, agricultural, and economic development of the various Federal reclamation projects, and are used extensively in schools and colleges.

The United States Public Health Service of the Treasury Department has made a few films dealing with special phases of public health work which are used for exhibition before medical societies and other special audiences. The Women's Bureau of the United States Department of Labor has produced and is circulating four films dealing with employment conditions of wage-earning women. The Tennessee Valley Authority has produced four films during the past year which are available for general distribution. These films depict the work being done in the Tennessee Valley. The Federal Housing Administration has had a number of films produced for theatrical showings, which are now being released for school and club use. Two films depicting the activities of relief workers were produced in Los Angeles last spring under the auspices of the Federal Emergency Relief Administration; and this fall a Motion Picture Record Division has been established by the Works Progress Administration to record the progress on public works projects.

The combined yearly attendance at all the exhibitions of the Government's educational films amounts to only about 10,000,000 persons or one day's attendance at motion picture theaters. If all those who attended these Government showings were school pupils it would take more than three years for the 31,000,000 school children of America to attend one showing.

In addition to the agencies that actually produce and distribute motion pictures, a few Federal agencies carry on other motion picture activities. The Motion Picture Section of the Bureau of Foreign and Domestic Commerce exists for the purpose of promoting and developing the motion picture business in the United States and abroad. It keeps in close contact with the foreign departments of the individual producing and distributing companies; with the various trade associations in the industry; and with every possible source of reliable information both at home and overseas. It publishes this information in bulletins and pamphlets, as a means of extending every possible assistance in organizing, developing, and maintaining a

profitable export business for American producers and distributors of entertainment films; manufacturers and sellers of motion picture equipment; and producers, distributors, and exhibitors of non-theatrical (industrial and educational) films. Nothing is left undone to keep open the legitimate arteries of business—and therein lies the answer to what has been characterized so generously by the motion picture industry as "a job well done."

A service of altogether different type is being launched by the Motion Picture and Sound Recording Division of the National Archives. This division is concerned with the acquisition, storage, maintenance, and cataloguing of historical activities of the United States. It has also the responsibility of arranging for recording important historical events upon film or disk; and the reproduction and distribution of films and recordings of historical value for the convenience of Government departments and educational agencies. It is interesting to note that the National Archives is the first central depository of all Government films, and is arranging projection rooms for their exhibition along with other meritorious films.

In harmony with the general function of the United States Office of Education, the Radio and Visual Education Section serves as a national clearing house for the exchange of information about the production, distribution, and use of motion pictures for educational purposes.

Scarcely a week passes but an urgent request is made upon the United States Office of Education to take a more active part in having films made and distributed to the CCC camps and schools of the Nation. Other plans call for some form of Federal aid to schools for purchasing equipment to assist in the school motion picture work. Judging from the large number of plans and requests for grants from the four billion dollar relief fund, many persons in or near the motion picture industry believe that the Government should assist further in the development of the educational film field.

The Office of Education is also interested in extending and facilitating the use of films for educational purposes. That is the reason for the title selected for this paper: "Is the Federal Government Interested in Educational Films?" The answer is that various bureaus and independent agencies within the Federal Government are interested, but there is a woeful lack of coördination of the work of these agencies. In fact, from the standpoint of educational service, the whole non-theatrical field is chaotic and disorganized.

Extensive research and experimentation have demonstrated that the motion picture has great educational value. Many books, monographs, and articles have been written and addresses delivered before such bodies as the Society of Motion Picture Engineers to stress the innumerable ways in which the motion picture can be used to aid education. Yet, less than ten per cent of the 276,000 schools in the United States make systematic use of motion pictures for instructional purposes, and they do not make ten per cent of the use of the film they would make if an adequate supply of suitable films were available. More than $3,000,000,000 is spent annually on education in the United States, and over a million teachers employed. In addition to the potential school market with its millions to be served, the CCC camps, and tens of thousands of clubs need specialized educational film service. A survey of the educational film field made by the Office of Education[1] about a year and a half ago indicated beyond a doubt that an American film institute should be established to facilitate the production, distribution, and use of educational films.

At first it was deemed wise for the Office of Education to take the initiative in the formation of the institute, with the Government, organized education, and the motion picture industry all participating. Later, however, the American Council on Education, a non-governmental agency, took the initiative, and is now sponsoring the establishment of such an institute.

It is not contemplated that a new producing industry would be set up in Washington or elsewhere. Instead, it is definitely recognized that the motion picture industry should be expected to come forward and use its expert technical services for supplying the numerous films, projectors, and other equipment necessary to make an efficient accomplishment of this vastly needed service. Members of the SMPE can render invaluable assistance by developing tougher, more durable film; more uniformly good reductions of 35-mm. to 16-mm; and a 16-mm. combination sound-silent projector that requires little skill to operate and a minimum of servicing—not to overlook the need for international standardization of sprocket placement, and so forth. Close collaboration of educators, motion picture producers, and government officials is needed if the vast potentialities of the educational film are to be developed.

REFERENCE

[1] KOON, C. M., and others: "Motion Pictures in Education in the United States," *Univ. of Chicago Press*, Chicago, Ill. (1934).

A NON-THEATRICAL, INTERNATIONAL SERVICE ORGANIZATION—THE AMATEUR CINEMA LEAGUE*

R. W. WINTON**

Summary.—*After discussing briefly the evolution of non-theatrical motion pictures, particularly of the amateur type, and discussing briefly the technical and practical requisites of the non-theatrical filmer, the organization of the Amateur Cinema League is described and its aims and purposes discussed.*

Discussion of a non-theatrical, international service organization in the motion picture field before this body is logical because the Society of Motion Picture Engineers has always interested itself in the non-theatrical, as well as the theatrical application of the medium.

Early years of motion pictures were chiefly theatrical years, because the abstract thinker, the scientist, and the technician followed, rather than preceded, the exploiter and practical user. Based, to be sure, upon very original and quite scientific experiments, the actual birth of the movie took place in the showman's booth and not in the laboratory.

During this phase of evolution, non-theatrical pictures were often studio by-products, made either by studios themselves, by technicians of studios in periods between studio assignments, or by free-lance newsreel cameramen whose chief revenue came from studio sales. The studio technic and the studio mystery surrounded non-theatrical as well as theatrical films, and the non-theatrical user took what the studio system gave him. He was continually dissatisfied with what he got—particularly the educator and the non-commercial projectionist—and the industrial advertiser soon found that his early hope of persuading paying theater patrons to look at his sales pictures was vain. Storage vaults of business concerns still carry some of these failures. The theatrical film industry was too much occupied with photoplays to divert its attention to exploiting the non-theatrical field.

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* Presented at the Fall, 1935, Meeting at Washington, D. C.

** Amateur Cinema League, Inc., New York, N. Y.

Somewhat over a decade ago, the practical application of substandard film set in motion a series of events that changed the status of non-theatrical movies from that of a subservient and incidental concomitant of theatrical pictures to that of an increasingly independent activity. Before the amateur movie had time to congeal into any set category, as had the theatrical photoplay, personal filmers were widening the definition of movie amateur into a broader meaning, and were producing with a hastily improvised technic, what has actually become a well recognized, non-theatrical type of movie. This new type includes films made for family records; travel movies; experiments in scenic pictures made with artistic intent; tentative, and sometimes full fledged, photoplays; studies of athletic form and records of games—all these of the extremely personal character in the non-theatrical film category. The new type includes also medical and surgical films, pictures made by the scientist either to illustrate a difficult process or to be used in instruction; movies produced by manufacturers and retailers, either to sell products to the public or to train employees; and films designed to accomplish propaganda of various kinds. These listings are by no means exhaustive. In general, it may be said that films are now used for almost as many purposes as is the printed word.

This extensive development of non-theatrical films, both for personal recreation and for practical application, has taken place on all the various film widths that have been made available. In general, cost has limited the majority of these non-theatrical movie ventures to sub-standard widths, although 35-mm. is used also. The important fact in this development is found in the liberation of non-theatrical filming from studio methods. As a matter of fact, non-theatrical filming has, from the very first, been so different from photoplay making that the usual studio technic has not been properly applicable. Paradoxically, the typically equipped studio is unsuited to non-theatrical filming, and the studio personnel finds it difficult to refrain from employing elaborate equipment to handle simple situations, which propensity is likely to impart to a non-theatrical film a theatrical elaborateness that often defeats the real purpose of the effort.

There are certain considerations inevitable in discovering the underlying bases of non-theatrical filming, a lack of which may make for failure in such enterprises. One of these is the cost of film and equipment. In theatrical production, the expense involved may

generally be treated as a kind of rough revolving fund, because the picture is to be distributed upon the basis of direct sale, lease, or rental; and money will be received as a specific and definite result of the transaction. This revolving fund theory is not valid with non-theatrical pictures, except in a very small minority of instances, and whatever cost is incurred is absolute, with the returns either in terms of personal satisfaction, reaction, service, or in terms of indirect financial profit that can not be predicted with any certainty.

Since the greatest amount of non-theatrical filming is done by individuals, either as amateurs or practical movie makers, another consideration is that of simplicity of equipment. The elements here are facility of handling—with complexities and technical difficulties brought to the lowest degree—and easy portability. As an example of this requisite of simplicity, the use of a tripod, which is a *sine qua non* of theatrical camera work, becomes an ever-present problem with the personal filmer. He must balance the unquestioned advantage of this important filming aid against the difficulty of employing it, both because of the commotion he will create by setting it up in a crowded place, and because of the addition of its weight and bulk to that of the other equipment he must take with him, such as exposure and distance meters, filters, extra film, and other accessories.

Study and training are requisites for the non-theatrical filmer who is not a product of the apprentice and experience school, as is generally the case with the studio worker. The character and scope of this training is a third basic consideration in any attempt to serve non-theatrical workers. An obvious division of instruction is found in the study of how to use the mechanical tools, camera, film, and accessories, and what to do with the tools, once one has learned their use—which gives us two pedagogical subjects, camera technic and continuity. This all-around training is not followed in the education of theatrical filmers, where the studio organization is so complex that specialists are developed to meet each need as it arises. In non-theatrical filming, the technic of direction, which bulks so large in studio work, assumes a very modest proportion, and the non-theatrical worker who deals more largely with inanimate than with animate subjects, or who, in dealing with animate subjects is more concerned with catching their natural actions than with inspiring them to dramatic efforts, must chiefly learn the art of making the people whom he films unselfconscious, so that his records may be authentic rather than theatrical.

After the non-theatrical picture is shot, there arises the problem of processing it and the concomitant question of reproducing it in distributable quantity, if such is necessary to the purpose. Suitable projection for all the different conditions in which non-theatrical films are shown is a problem so familiar that it need not be elaborated. It is felt desirable only to emphasize again that blindly following theatrical standards in projection will never solve the difficulties of non-theatrical showings.

The final considerations in determining what shall be an adequate service to non-theatrical film workers are those of distribution and the care of film prints. The latter is relatively easy, allowing for the ever-present factor of human carelessness; but the former has been the rock upon which not a few commercial non-theatrical filmers have come to disaster. Distribution is a chore and an unpleasant one. The purely personal and non-commercial filmers are popularly supposed not to be concerned with it, but the experience of a decade in working with them has shown that these movie makers hunger for audiences just as strongly as do the owners of a typical "industrial" who have invested a sizable amount of money in a filming venture.

Upon the underlying bases of non-theatrical filming just discussed, it is possible to construct an analysis of the duties of a service organization for non-theatrical movie makers. Since filming is a world-wide activity, a non-theatrical movie service body should find aids that can be offered to those both far from and close to its headquarters and should not neglect its distant members. Since the facilities of such an organization are to be offered to all its members, it must meet the largest demand most fully, and must take care that its special services do not overshadow the general and absorb too much of the time and effort of the staff. It must not forget the important duty of propaganda and the popularization of non-theatrical filming in all its phases. It must serve a continuous crop of beginning filmers, and it must guard against the danger of a formalized routine whose lifelessness can not be concealed from the students.

Such a service body must not be entrapped by technicalities or technical nomenclature. Non-theatrical filmers lack terminologies and nomenclatures and are generally disinclined to acquire them. If the counsel they receive is couched in the shorthand of technical terms, they will often reject it and become irritable toward those who offer it. Opposed to this danger of becoming too technically complex in statement is the other peril of appearing too puerile. Probably

a safe course is first to make certain, by examination and reëxamination, of the accuracy of the facts and the soundness of the advice presented, and then to state these in language of great simplicity, free from special terminology, so far as may be.

Our service body must establish early and mutually respectful relations with the industry that supplies the tools of non-theatrical filming. The easy path would be for it to draw aside its skirts from any contact with commercial enterprises and to announce that it stands boldly for the interests of the user, as opposed to those of the seller. However, unless a service body commands the respect of the industry that supplies non-theatrical filming tools, it can not make any effective recommendations to that industry on the important matters of the nature and cost of the equipment offered, which is certainly one of its major obligations. It must recognize manufacturing and distribution problems and avoid taking any illogical viewpoint allegedly in the interests of users as opposed to those of purveyors. It must and can serve to translate the attitude of movie makers for the supplying industry and that of the industry for filmers. This service body must be willing to undertake activity that lies in the no-man's land between purveyor and consumer of cinematographic goods, and it must, at times, risk being misunderstood by both. As a specific example of this work, there may be mentioned the question of the distribution of non-theatrical films to their audiences, for which no very satisfactory answer has yet been found. In venturing into these twilight zone activities, our service organization must not permit itself to be led into commercial enterprises.

Founded upon the basic considerations and conscious of the duties that have been outlined, an international non-theatrical movie service body might develop its program in the following terms:

(*1*) A training system divided into the two broad departments of equipment technic and continuity, serving beginners and advanced workers equally well and meeting individual needs of members as they arise.

(*2*) An information and stimulation system, to publish periodical and occasional magazines, books, and shorter items.

(*3*) A film examination and criticism system.

(*4*) A system of aid to other organizations of a non-commercial kind.

(*5*) A system of coöperation with commercial concerns, for the broad development of non-theatrical filming.

(*6*) A system of service for special fields and special problems.

(*7*) A method of dealing with international, national, and regional problems, based upon the concept of service without domination or regimentation.

We have considered what might be termed the ideal yardstick by which the organization and operation of our service body could be measured. In order that we may compare the actual to the ideal, it will now be desirable to sketch briefly what the Amateur Cinema League has accomplished in working out a part of this program.

Founded in 1926, the Amateur Cinema League now serves non-theatrical filmers in more than sixty countries of the world. It is owned and controlled entirely by its membership and enjoys no grants or subsidies from any source. It makes no profits for any stockholders, as it is without capital stock, and it is entirely free from any outside control or influence.

The first need of the League, in its organization year, was to develop a unity and a solidarity among film amateurs. This was accomplished by the publication of its monthly magazine, *Movie Makers;* by aid to local groups in setting up filming, discussion, and photoplay-making clubs; and by the establishment of a system of exchanging films from one member to another. By these means, isolated movie makers became aware of each other and found a method of exchanging experiences and comparing technics. All three activities have been maintained and expanded.

The League had to provide service, but first it had to create this service. It may be said that the present technic of non-theatrical film training and service that the League employs has been developed largely from the observation of the work of League members, as they first tried to parallel Hollywood and then diverged from Hollywood standards and methods. The first calls for help from amateurs were in the field of photoplays, and scenarios of any and every kind were eagerly sought by them. Later, the more basic and lasting matters of how to make family, travel, business, and scientific films intelligible in terms of cinematic grammar began to interest non-theatrical filmers, and that distinctly new thing, the continuity of simple, non-theatrical movies, emerged into reality. In all this service, we had continually to emphasize simplicity and non-technical clarity. In addition to this consulting aid to members, the League undertook the publication of special bulletins and monographs, because the space in its monthly magazine was found insufficient to cover certain topics exhaustively. Later, there developed what is now accepted as the basic text of non-theatrical filming, *Making Better Movies*, now in its second edition. Film examination and criticism began early and have increased extensively, and the League has

aided in planning and advising on the filming of pictures of every conceivable type for members in every corner of the earth, discussing with the authors of the enterprises the kind of equipment to use, the treatment, the working out of the treatment, the titling, the projection and, indeed, every phase of their problems. The finished product is examined and changes are suggested. At times, the telegraph and long-distance telephone are used when work would otherwise be delayed. Special services have been worked out in connection with plots and titles. We try to make it easy for members to ask for help by supplying them with cards upon which, by a pencil check, they may indicate their needs. We have worked with manufacturers of ciné equipment in the development of new and the improvement of existing items. We have accepted the responsibility of representing both users and purveyors in international and in legislative matters. In all these, we serve individual amateurs, scientists, organizations, and business concerns, both large and small, for the same membership fee. Departments of the national governments of various countries, state units, national societies, and some of the greatest corporations in the United States use Amateur Cinema League services.

As upon the professionals, color and sound descended upon us and brought a whole set of new complexities to be worked out which we had to face just as we were getting on our feet with a new technic of personal movie making. We have had to keep at least one jump ahead of our students in our information and training work and to keep a part of our mind fixed upon what would happen six months or a year ahead. We have been hounded by movie makers to persuade somebody to provide this or that item of equipment and we have tried to check demand against probable sale and to present reasoned recommendations to manufacturers. We have been faced with legislative problems in many places, as old laws were rewritten and the revisions, just as the originals, took no account of non-theatrical problems or filmers. We had to face the difficulty of codes in the United States, under NRA, and to serve both users and purveyors in this complicated episode. We were able to be of some service in achieving a modification of the tariff law, in 1930, to permit free entry of personal films into the United States under certain restrictions. It has been a pleasure for us to second the fine work of the Society of Motion Picture Engineers in attempting to establish unified motion picture standards for use in all countries and we pledge our continuance of support.

In relations with local groups and regional and national bodies, we have made no formal affiliations, nor have we asked dues from their local members or demanded obligations, although a number of such organizations have League membership. We have served clubs, as such, without charge. Our service is centralized, which we regard wise, but it carries with it no control or domination of those served. We have avoided commercialization of any League service or activity. We make no purchases or sales for members and do not favor discounts for them. We have been friendly with the industry supplying the tools of personal movie making but we have not subjected ourselves to its domination. It is worthy of note that this industry has "leaned over backward" in avoiding any appearance of wishing to control the policies of the League. We have not rendered special services for extra fees but have given all members what we had to offer them at a uniform membership rate. We have maintained an entire independence in the editorial policy of our publications. We have been careful to avoid premature and limiting definitions. As an example of this, we have steadfastly refused to define a film amateur, believing that the future of non-theatrical filming is so broad that a definition at this time would be absurd. We have not undertaken any tests of equipment or tried to place approval or disapproval upon any items presented. The one test is whether we permit an item to be advertised in our monthly publication, and, even there we do not indicate why we accept or reject. Our broad policy in this regard is to see that our magazine advertises only those objects or services that are believed by us to be practical and operable, and to offer a reasonable value at the price fixed. By now, we may lay claim to a few basic policies, although another might call them only prejudices. In our operations of all kinds, we try to remember that:

(*1*) The future of non-theatrical filming is the joint concern of those who make equipment, of those who sell it, and of those who use it, and all these can work together successfully.

(*2*) Service is more valuable to members than social reunions.

(*3*) Technicalities that can not be translated into plain language are not simple enough for general use.

(*4*) Whether he is a family filmer, a practical filmer, a scientist, or one who sells his film-making skill for profit, the League shall have something for every non-theatrical movie maker.

(*5*) A service body is a poor place for organization politics.

(*6*) Regimentation is the death of service.

(*7*) An international body gets farther by friendship than by controversy.

PHYSICAL TESTS ON CELLULOSIC FILMS, AND THEIR REPRODUCIBILITY*

S. E. SHEPPARD, P. T. NEWSOME, AND S. S. SWEET**

Summary.—*When all experimental errors of testing are adequately minimized, cellulose ester sheets show a dispersion of tensile strength values higher than that found for metal strips and wires. The dispersion of "yield point" values is much less than that of tensile strength.*

It is suggested that the lowest value (or, at any rate, the bracket of values lower than the average) of tensile strength for a number of tests equivalent to a given film length is a better measure of the probability of failure in performance than the average value. However, for comparative rating, it appears that generally the ratio of lowest to average is fairly constant.

The physical tests discussed in this paper are general, in the determination of the strength of materials, whether metal, paper, cellulosic, or similar films, used for photographic supports or packaging; or, again, rubber. Amplifications and variations of such tests are developed further which are intended to bring the tests into closer relation to specific practical requirements and durability in use.

One of the chief difficulties in testing and development laboratories is the evaluation of individual strength tests in relation to performance tests. This is particularly the case when one is concerned not with the strength in relation to static loading, but in relation to cyclic dynamic loading under conditions simulating use. It is not the purpose to discuss this here, but to report upon some investigations as to the reproducibility of physical strength tests of cellulosic film support materials. Since the strength of a chain is that of its weakest link, it is felt that neither a single value, nor an average value of a number of physical strength tests of a given material, can be a measure of the probability of failure in performance; but that it is more reasonable to consider the *lowest value* of a *number of tests equivalent to the working length* in question as the significant strength figure. Rela-

* Presented at the Fall, 1935, Meeting at Washington, D. C. Communication No. 568 from the Kodak Research Laboratories.

** Eastman Kodak Co., Rochester, N. Y.

tively, it may happen that as between different materials, these lower limit figures may be proportional to the average values—for a sufficient number of tests—but there is no *a priori* certainty about this; it may be stated that statistics of the tests so far available indicate this to be generally true, but not invariably.

That a number of tests should give values having a certain distribution or dispersion is only to be expected—the important thing is the extent of the dispersion, and its significance. Evidently, if the distribution of values is very narrow, in other words, if the observations show a very small spread, and the reproducibility is high, the homogeneity and uniformity are so also. In this respect the investigation overlaps with the first part of one by Jones and Miles on the tensile strength of nitrocellulose films,[1] and it will be of interest to compare some of our results with theirs, particularly since we have also compared cellulose nitrate films with cellulose acetate.

MATERIAL

The material for the most part was prepared in the laboratory by a procedure to be described. Jones and Miles, in the investigation cited, compared films coated in the laboratory with two commercial film supports of cellulose nitrate. The latter showed a somewhat lower standard deviation,* from which it was concluded that the preparation in very large quantity might result in greater uniformity of local strain upon drying than in the smaller laboratory coatings. There is involved in this, however, both the manner of the laboratory coating and that of the manufacturing procedure. It does not appear, either from Jones and Miles' results or our own, that the differences between laboratory-prepared samples and regular products are very considerable in this respect. They are of interest to the manufacturer rather than to the user, to whom these results are chiefly presented.

METHOD OF PREPARATION

Jones and Miles used the method of coating upon a mercury surface of circular section. In the case of rather thin films, this tends to give a nearly isotropic sheet, free from directional strains,[2] since the liquid surface allows a uniform retreat of the drying film. We have ourselves used a method of coating upon levelled glass plates,

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* *Vide infra.*

using a doctor-knife to adjust for a desired thickness. Films so coated are not isotropic—McNally and Sheppard[2] showed that their properties tended to approach those of uniaxial crystals, but are sufficiently uniform either along or across the direction of flow and coating. Coating from acetone or acetone–methyl alcohol solution was carried out under standard conditions of humidity and temperature, followed by precuring at 50°C. and final curing at 100°C., by which all but traces of solvent were removed. The samples were conditioned for 24 hours at 25°C. and 45 per cent relative humidity before being tested.

APPARATUS AND CONTROL

The dynamometer used was of the Schopper type, previously described.[3] It has been shown by Sheppard and Carver[4] that films of

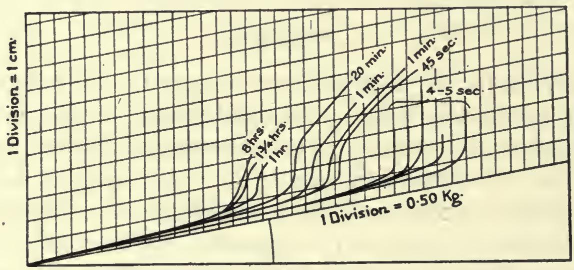


FIG. 1. Showing dependence of yield point and breaking load of cellulose ester films upon rate of loading.

cellulose esters are imperfectly elastic, and flow slightly even under very small loads. Consequently, the values of "yield point" and "breaking load" obtained depend upon the rate of loading, a result illustrated by Fig. 1, reproduced from Sheppard and Carver's paper. While yield points and breaking loads may be read from the automatic tracings, they may be obtained also from the sector scale of the pendulum weight, the former as the point at which the load first remains stationary,* the latter as the final value at break. It will be remembered that the "yield point" is simply the point at which the flow equals the rate of application of pull, but for a fixed speed it can be determined with good accuracy and is of value equal to, perhaps greater than, the "breaking load." In all the tests dealt with in this paper, the lower grip was moved at a speed of 8.6 cm. per minute.

* Relatively.

In order to check the performance of the instrument, a considerable number of tests was run upon metal wires and sheet-strips. These were of high uniformity of thickness, and overlapped the cellulose esters in regard to mechanical strength, as shown in Table I. With

TABLE I

Physical Constants of Metals Compared to Cellulose Acetate

Metal	Hardness	Tensile Strength (Kg. per Sq.Mm.)	Young's Modulus (Dynes per Sq. Cm.)	Modulus of Rigidity (Dynes per Sq. Cm.)	Bulk Modulus (Dynes per Sq. Cm.)
Lead	1.5	2	1.7×10^{11}	0.7×10^{11}	0.75×10^{11}
Tin	1.5	3	5.0	2.0	5.0
Cellulose Acetate	2.0–2.5	10	0.3	0.06	..
Aluminum	2.0	18	7.0	2.5	7.0
Copper	2.5	28	10.0	4.2	12.0
Brass	3.0–4.0	100	9.2	3.7	6.1

copper wire No. 18 B&S gauge, 0.040 inch in diameter, an average breaking load of 19.0 kg. was found, with a *maximum* variation of 1.5 per cent; a yield point of 18.0 kg., *maximum* variation 2.0 per cent; elongation, 39 per cent, *maximum* variation 12 per cent. Tin and lead foil also gave results of similar character. In general, as compared with the cellulosic materials, these metals and alloys showed considerably lower dispersion of the values for tensile strength and elongation.

TEST PIECES AND PREPARATION

The ultimate strength of many materials has been supposed to be greatly affected by the presence of cracks, even superficial cracks or scratches. Sheppard and Sweet[3] have shown that scratches upon the surface of film base affect the strength only inasmuch as they reduce the thickness at that point. Briefer[5] has stated that "even a slight nick, so slight as to be imperceptible to the naked eye, will shorten the elongation curve 50 per cent or more." In confirmation of this, a nick of only 0.002 inch was found to produce a drop of 20 per cent in strength and of 25 per cent in elongation.[6] In consequence, the method of shaping the test-pieces from larger sheets is of considerable importance. It has been established that cutting by shearing action with a knife (paper trimming board) is not as reliable as slitting with a special cutting edge. In the latter case, searing the edges of samples made no improvement in the reproducibility

of tests, indicating that nicks which might start a tear were substantially absent.

In this connection, the length of the test-strip is of some importance. The probability of serious cracks or nicks being present in the edges will be proportional to the length of the strip. Examination of a series of different lengths gave a slightly higher mean value for the shortest, 2 cm., strip.

Length	Mean Tensile Strength (Kg.)
2 cm.	12.9
5 cm.	12.6
10 cm.	12.8
15 cm.	12.7

In most of the tests described here a test-strip of 2 cm. between the grips was used.

THICKNESS AND UNIFORMITY OF THICKNESS

Experiments in this laboratory have shown that within the range significant for film support, strips of different thicknesses of the same material give identical tensile strengths per unit of cross-section. Hence, the actual breaking load of strips of the same width varies directly as the thickness. Jones and Miles, in the work referred to, have emphasized the importance of uniformity of thickness for uniformity of behavior in tensile tests. In our experiments all thickness measurements (both original and at point of break) were made with a Federal thickness-gauge, reading to 0.0001 inch, which had been checked against an optical gauge. In addition, uniformity of thickness was further tested with an automatically recording gauge. The variations of thickness observed are illustrated in Table II, for three different materials.

TABLE II

Sheet	Average Thickness	Total Per Cent Variation	Thickness at Break	Total Per Cent Variation
Acetate—1	0.00745	1.3	0.00655	4.5
Acetate—2	0.00525	2.0	0.0045	4.4
Nitrate—1	0.00825	1.2	0.00735	4.0

It appears evident that the variation of tensile strength, deduced from reducing the breaking loads to values per sq. mm., is much greater than would be caused by variation in thickness and consequent error in apparent tensile value.

FIG. 3.

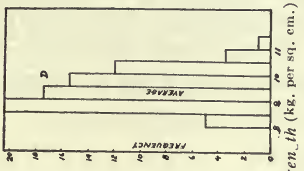


FIG. 2.

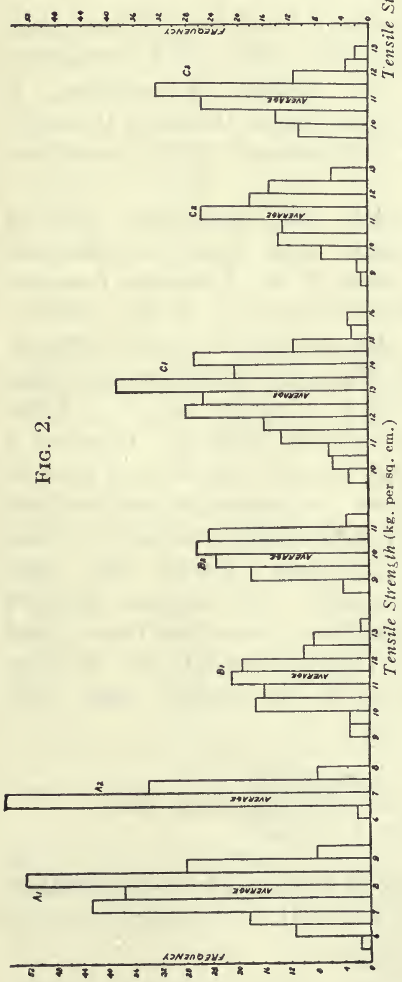
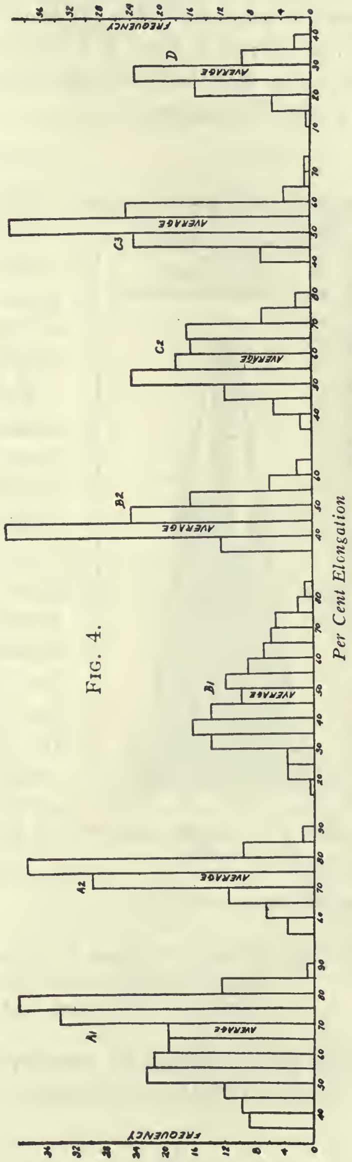


FIG. 4.



FIGS. 2, 3, and 4. Tensile strength and elongation of various materials listed in Table III plotted against frequency.

FREQUENCY POLYGONS AND DISTRIBUTION CURVES

The data for tensile strength and elongation of the various types of material listed in Table III have been plotted as frequency polygons, and are shown in Figs. 2, 3, and 4. It was found that some of the distributions were well represented by a symmetrical or Gaussian type of probability curve

$$y = ke^{-h^2x^2}$$

where h and k are constants. When $x = 0, y = k$; *i. e.*, the maximum ordinate. The value of h, sometimes called "the measure of precision," is greater according as the curve is steeper in the neighborhood of the central ordinate.

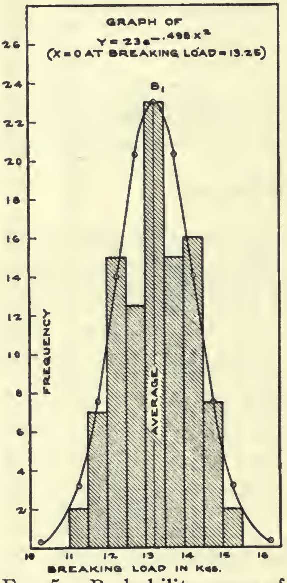


FIG. 5. Probability curve of distribution.

Evidently, the distribution must be symmetrical with regard to higher and lower values of the deviations from the mean for this type to fit the observations. An example is given in Fig. 5. The distribution is well fitted by taking $k = 23$, $h = 0.075$; for $x = 0$ the average value is 13.25 kg. However, a number of the observations gave more or less "skew," or asymmetric distributions, the asymmetry being invariably in favor of, or "weighted" toward, the lower tensile bracket. The *standard deviation* of thickness was determined from a large number of measurements on the supports used in the strength tests, with the following results:

B type: Average thickness, 0.142 mm. (0.00558 inch)
Standard deviation of thickness, 0.002 mm. (0.0008 inch)
Standard deviation of thickness, 1.5 per cent

These results should be compared with those given for the variation of tensile strength and elongation in Table III.

AVERAGES

The *average values* of tensile strength, yield point, and elongation are the arithmetical means of all the values. The *average deviation*

is the arithmetical mean of all the deviations from the average, irrespective of sign. The *standard deviation* (*S.D.*) is the mean square-root of the squares of deviations from the mean.

TABLE III

Standard Deviation of Tensile Strength and Elongation

Type	Thickness (Approx.) (Mm.)	Number of Values	Tensile Strength: Average (Kg./Mm.^{2})	Tensile Strength: Standard Deviation (Kg./Mm.^{2})	Tensile Strength: Per Cent Standard Deviation	Elongation: Average (Per Cent)	Elongation: Deviation (Per Cent)	Elongation: Per Cent Standard Deviation
A_1 Acetate	0.190	200	7.7	0.76	9.9	65	13.2	20.3
A_2 Acetate	0.190	100	7.0	0.31	4.4	73	5.9	8.1
B_1 Acetate	0.133	100	11.3	0.90	8.0	48	13.8	28.5
B_2 Acetate	0.133	100	10.0	0.60	6.0	45	5.4	12.0
C_1 Nitrate	0.203	200	12.9	1.25	9.7	..	..	..
C_2 Nitrate	0.133	100	11.1	0.85	7.6	57	8.5	15.0
C_3 Nitrate	0.133	100	10.9	0.67	6.2	52	4.8	9.2
D Acetate	0.127	75	9.4	0.53	5.6	26	4.7	18.0

Modal values of tensile strength, *etc.*, are the values having the greatest frequency of occurrence in the frequency curves.

Plots of log T (tensile) against frequency, and again of log T

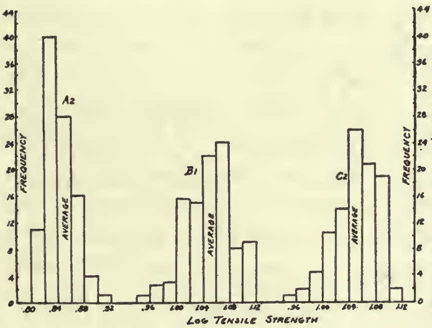


FIG. 6. Log tensile strength *vs.* frequency.

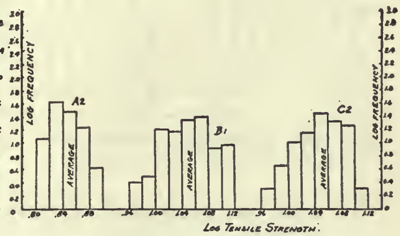


FIG. 7. Log tensile strength *vs.* log frequency

against log F (frequency) tended to give more symmetrical curves (Figs. 6 and 7). The latter plot, if parabolic, indicates a distribution function of the type

$$y = Ke^{-h^2(\log x - \alpha)^2}$$

which has been used successfully in the representation of the size-frequency distribution of precipitated particles and crystallites.[7]

REPRESENTATIVE VALUES AND REPRODUCIBILITY

It was stated in the introduction that the question be raised as to whether the *average* value of a tensile test was the most representative value for a material used in a film, or whether the *lowest* value observed should not be considered. Table IV shows that so far as the material examined goes, a large proportion show a fairly good proportionality between the *average* and the *lowest* values.

The samples A_2 and C_1, which deviate most, were distinguished by A_2 having the most symmetrical, and C_1 the most asymmetrical, or "skew," distribution.

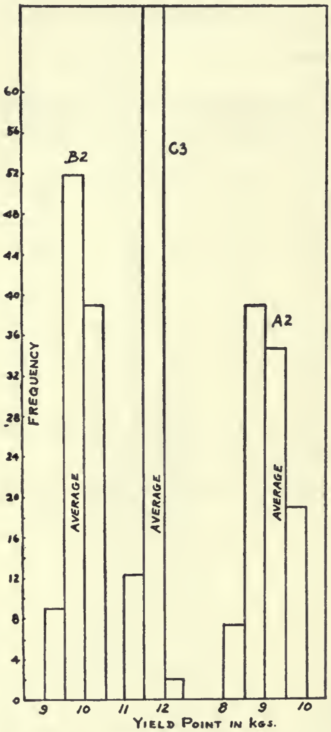


FIG. 8. Showing narrower dispersion of yield point values.

YIELD POINT

The nature of the "yield point" and its dependence upon the testing conditions has already been discussed. It may be pointed out, however, that in practically all cases the dispersion of values, as measured by the *standard deviation,* was much less than that of the breaking load, *i. e.*, of tensile strength. This corresponds to the fact recognized in dealing with the strength of materials that the ultimate strength is affected by a variety of casual extrinsic factors. The narrower dispersion of yield point values is illustrated in Fig. 8.

REPRODUCIBILITY, OR NUMBER OF TESTS REQUIRED FOR AVERAGE VALUE OF GIVEN ACCURACY

The arithmetic mean of all the individual values in a given test (tensile strength, *etc.*) was obtained. The individual values were placed successively in groups of 5, 10, 20, 50, *etc.*, in order of occurrence, and the average value of each group recorded. It will be sufficient to summarize the conclusions. The average of five dupli-

TABLE IV

Type	Average Tensile Strength (Kg./Mm.²)	Lowest Tensile Strength (Kg./Mm.²)	Highest Tensile Strength (Kg./Mm.²)	$\frac{\text{Lowest value}}{\text{Average value}}$
A_1 Acetate	7.7	6.1	9.34	0.80
A_2 Acetate	7.0	6.5	8.1	0.93
B_1 Acetate	11.3	9.0	13.1	0.80
B_2 Acetate	10.0	8.5	11.2	0.85
C_1 Nitrate	12.9	9.7	15.9	0.755
C_2 Nitrate	11.1	8.85	12.8	0.80
C_3 Nitrate	10.9	9.1	12.6	0.83
D Nitrate	9.4	8.2	10.6	0.87

cate tests was found to give average deviations from the mean ranging from:

2.7 to 4.5	per cent	Tensile
10.5 to 24	per cent	Stretch
8.7 to 12	per cent	Flexibility

But the average deviation from the mean is not an adequate measure of accuracy, which is better expressed as the variation between minimum and maximum values. From this it is concluded that the average of some 50 tests of tensile strength is necessary to be sure that differences of the order of 5 per cent are significant.

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FALL, 1936, CONVENTION

ROCHESTER, NEW YORK
SAGAMORE HOTEL
OCTOBER 12–15, INCLUSIVE

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HEADQUARTERS

The Headquarters of the Convention will be the Sagamore Hotel, where excellent accommodations are assured. A reception suite will be provided for the Ladies' Committee, which is now engaged in preparing an excellent program of entertainment for the ladies attending the Convention.

Special hotel rates guaranteed to S. M. P. E. delegates, European plan, will be as follows:

One person, room and bath....................	$ 3.50
Two persons, room and bath...................	6.00
Parlor suite and bath, for two.................	10.00
Parlor suite and bath, for three................	12.00

Room reservation cards will be mailed to the membership of the Society in the near future and everyone who plans to attend the Convention should return his card to the Hotel promptly in order to be assured of satisfactory accommodations. Registrations will be made in the order in which the cards are received. When the Sagamore Hotel is booked to capacity, additional accommodations will be provided by the Hotel Arrangements Committee at another hotel in the immediate vicinity of the Sagamore.

A special rate of fifty cents a day has been arranged for S. M. P. E. delegates who motor to the Convention, at the Ramp Garage, near the Hotel.

Golfing privileges may be arranged for any of the Convention delegates by consulting the Chairman of the Local Arrangements Committee.

TECHNICAL SESSIONS

An attractive program of technical papers and presentations is being arranged by the Papers Committee. Sessions and entertainment programs will be conducted at the Sagamore Hotel and at the plants of the Eastman Kodak Co. and the Bausch & Lomb Optical Co. in accordance with the tentative program which follows.

The attention of authors is directed to an announcement of the Papers Committee at the bottom of the inside cover of this issue of the JOURNAL. Those

who contemplate submitting manuscripts for the Convention should communicate with the Papers Committee as promptly as possible.

SEMI-ANNUAL BANQUET

The Semi-Annual Banquet and Dance of the Society will be held at the Oak Hill Country Club on Wednesday, October 14th, at 7:30 P.M. Motor-coach transportation will be provided to and from the Club by the Transportation Committee.

INSPECTION TRIPS

Arrangements will be made on the days when the inspection trips are conducted at the plants of the Eastman Kodak Co. and the Bausch & Lomb Optical Co. to transport the members to these plants. The members of the Society are also invited to be the guests of those companies at luncheon on those days.

PROGRAM

Monday, October 12th

9:00 a. m. *Sagamore Hotel Roof*
Registration
Society business

10:00 a. m.–12:00 m. Committee reports
Technical papers program

12:30 p. m. *Sagamore Hotel Main Dining Room*
Informal Get-Together Luncheon for members, their families, and guests. Brief addresses by several prominent members of the industry.

2:00 p. m.–5:00 p. m. *Sagamore Hotel Roof*
Technical papers program.

8:00 p. m. *Eastman Theater*
"Color Photography" (with demonstrations and motion pictures), Dr. C. E. K. Mees, *Vice-President in Charge of Research*, Eastman Kodak Co., Rochester, N. Y.

Tuesday, October 13th

9:00 a. m. Buses will be at the Sagamore Hotel to transport members and guests to the Kodak Research Laboratories at Kodak Park.

10:00 a. m.–12:30 p. m. Technical papers program in the auditorium of the Kodak Research Laboratories.

1:00 p. m. Invitation luncheon at Kodak Park Works of Eastman Kodak Co.

2:00 p. m.–5:00 p. m. Inspection tour of Kodak Park and the Kodak Research Laboratories.

The program for the evening of this day will be announced in a later issue of the JOURNAL.

Wednesday, October 14th

10:00 a. m.–12:00 m. *Sagamore Hotel Roof*
Technical papers program.

1:00 p. m. Invitation luncheon at Bausch & Lomb Optical Co. Transportation to the Bausch & Lomb plant will be provided. Buses will leave the Sagamore at 12:30 P.M. sharp.

2:00 p. m.–5:00 p. m. Inspection tour of the Bausch & Lomb plant.

7:30 p. m. *Oak Hill Country Club*
Semi-Annual Banquet and Dance of the S. M. P. E.: addresses and entertainment. Motor-coach transportation will be provided to and from the Club by the Transportation Committee. Coaches will leave the Hotel promptly at 7:00 P.M.

Thursday, October 15th

10:00 a. m.–12:00 p. m. *Sagamore Hotel Roof*
Technical papers program

2:00 p. m. Technical papers program
Society business
Adjournment of Convention

APPARATUS EXHIBIT

There will be no general apparatus exhibit because of the limited display space at the Convention headquarters. The Papers Committee, however, is arranging to hold the usual Apparatus Symposium, and would like to be notified of any papers for this session.

SOCIETY ANNOUNCEMENTS

BOARD OF GOVERNORS

At a meeting held at the Hotel Pennsylvania, New York, N. Y., July 10th, further plans for the approaching Convention at Rochester were developed, as described elsewhere in this issue of the JOURNAL. In addition, reports rendered by O. M. Glunt, *Financial Vice-President*, indicated that the Society was in a fairly satisfactory financial condition, and that the membership was continuing to increase somewhat, although at a rate slower than that during the previous year.

Nominations for officers for 1936 were completed, and ballots for voting upon these nominations will be mailed to the Active and Fellow membership of the Society the latter part of August.

The question of the policies to be followed by the Sectional Committee on Motion Pictures, ASA, of which the SMPE is sponsor, was discussed at great length, and arrangements were made to send a delegate to the forthcoming meeting of the International Standards Association at Budapest, beginning August 31st. At this meeting it is hoped that the long-continued differences as to 16-mm. sound-film standardization will be reconciled, and thought will be given also to possible standardization in the 35-mm. field.

FALL, 1936, CONVENTION AT ROCHESTER OCTOBER 12th–15th, INCLUSIVE

Details concerning the approaching Convention at Rochester, beginning October 12th, will be found on page 233 of this issue of the JOURNAL, and at the foot of the inside front cover page.

SOCIETY AWARDS

At the meeting of the Board of Governors described above, reports were rendered by the Progress Award and the Journal Award Committees, nominating the recipients for these awards, which are to be granted during the approaching Convention at Rochester next October. Announcement of the names of the recipients will not be made before the Convention, but at that time a complete description of their accomplishments and contributions to the motion picture art, which form the bases for granting the awards, will be published.

STANDARDS COMMITTEE

At a meeting held at the General Office of the Society on July 17th, study was made of the group of new drawings of the Standards which have been prepared during the past several months. The new drawings will be submitted to the American Standards Association for approval, and will form the basis of the American presentations at the forthcoming conference of the International Standards Association at Budapest, beginning August 31st.

ADMISSIONS COMMITTEE

At a recent meeting of the Admissions Committee, at the General Office of the Society, the following applicants for membership were admitted to the Associate grade:

ANDERSON, J. A.
Alexander Film Co., Colorado, Springs, Colo.

ASHTON, H.
3500 14th St., N. W., Washington D. C.

BACH, W.
431 Homestead Ave., Mount Vernon, N. Y.

BONZGOV, V.
Mazata str. 22/24, Apt. 2F, Leningrad, U. S. S. R.

BOWERS, V. M.
5508 S. Union Ave., Chicago, Ill.

BOYLE, W. E.
1215 E. 18th Ave., Denver, Colo.

BRAGG, H. E.
38 N. Barnet St., East Orange, N. J.

BRANDON, J. M.
306 Georgia Ave., Lorain, Ohio.

BYERS, J. K.
11 Mount Felix, Walton-on-Thames, Surrey, England.

CORTISSOZ, E. J.
859 N. Las Palmas Ave., Hollywood, Calif.

DAVIS, H. A.
1437 Jackson Blvd., Chicago, Ill.

DAY, A. R.
2033 N. Berendo St., Hollywood, Calif.

DONALD, R. R.
1022 Ninth St., N. W., Canton, Ohio.

FONG, P.
107 Des Voeux Road, Central Hong Kong, China.

GORDON, V. H.
459 W. 22d St., New York, N. Y.

HALLIDAY, E. N.
6982 Owen Ave., Chicago, Ill.

HENIUS, W. M.
39 Byramjee Jeejibhoy Road, Bombay-Bandra, British India.

HOUGH, G. W.
1043 S. Olive St., Los Angeles, Calif.

INNAMORATI, I. L.
1, Piazza Indipendenza, Rome, Italy.

IRELAND, P.
481 Lake Ave., Rochester, N. Y.

JACOBSEN, I.
c/o Balaban & Katz Corp., 175 N. State St., Chicago, Ill.

JENNINGS, J.
399 Fullerton Parkway, Chicago, Ill.

KALMANSON, V.
Leontievsky Pereulok dom 11, kv. 4, Moscow, U. S. S. R.

KENNEDY, K. W.
421 E. Maple Ave., La Grange, Ill.

KILLMAN, R. T.
744 Benton Ave., Nashville, Tenn.

KOJEVNIKOV, G.
Lesnoy Propect, 37, Korpus 6, Apt. 104, Leningrad, 100, U. S. S. R.

KUSMIERZ, J. F.
P.O. Box 203, Chicopee Falls, Mass.

La Tart, L.
118 Hatch St., Syracuse, N. Y.

LATENER, L.
Warner Bros., Earle Theatre Bldg., Philadelphia, Pa.

MARCUS, G. K.
1923 81st St., Brooklyn, N. Y.

MATHEWSON, W.
Thief River Falls, Minn.

O'BRIEN, W. S.
353 W. Broadway, Waukesha, Wis.

ODDIE, C. M.
1064 Mills Bldg., San Francisco, Calif.

PHILLIPS, R. G.
2901 Paririe Ave., Chicago, Ill.

ROESSNER, C. H.
Da-Lite Screen Co., 2723 N. Crawford Ave., Chicago, Ill.

SCHAEFER, E. J.
5938 Lakepointe, Detroit, Mich.

SCHWALBERG, A. W.
16 Wilson Drive, New Rochelle, N. Y.

SICHELMAN, J.
779 Riverside Drive, New York, N. Y.

SOKOLOV, S.
Lusinovskqya, 40, Apt. 19, Moscow, U. S. S. R.

SORKIN, M.
Nine Austin Park, Cambridge, Mass.

STEPANIAN, A. M.
Siratsky pereulok dom N116, Apt. 186, Moscow 26, U. S. S. R.

SWANSON, A. B.
1152 N. Sycamore Ave., Hollywood, Calif.

TOWNSLEY, M.
4045 N. Rockwell St., Chicago, Ill.

TROLLOPE, E. R.
430 S. Lincoln St., Casper, Wyo.

VAN LEER, O.
Carel Reinierszkade 299, The Hague, Holland.

WIENKE, E. J.
285 Forest Ave., Glen Ellyn, Ill.

In addition, the following applicants have been admitted by vote of the Board of Governors to the Fellow and Active grades:

CAHILL, F. E. (F)
321 W. 44th St., New York, N. Y.

BENDHEIM, E. McD. (M)
19–22 22d Drive, Astoria, L. I. C., New York.

McCOLLUM, A. B. (M)
805 W. Lincoln St., Hoopeston, Ill.

PEREYRA, M. (M)
O'Donnell, 41 Madrid, Spain.

SCHUMACHER, E. W. (M)
160 Fifth Ave., New York, N. Y.

THRASHER, F. M. (M)
100 Washington Sq., E., New York, N. Y.

JOURNAL

OF THE SOCIETY OF

MOTION PICTURE ENGINEERS

Volume XXVII **SEPTEMBER, 1936** **Number 3**

CONTENTS

JOURNAL

OF THE SOCIETY OF

MOTION PICTURE ENGINEERS

SYLVAN HARRIS, EDITOR

Subscription to non-members, $8.00 per annum; to members, $5.00 per annum, included in their annual membership dues; single copies, $1.00. A discount on subscriptions or single copies of 15 per cent is allowed to accredited agencies. Order from the Society of Motion Picture Engineers, Inc., 20th and Northampton Sts., Easton, Pa., or Hotel Pennsylvania, New York, N. Y.

Published monthly at Easton, Pa., by the Society of Motion Picture Engineers.

Publication Office, 20th & Northampton Sts., Easton, Pa.

General and Editorial Office, Hotel Pennsylvania, New York, N. Y.

Entered as second class matter January 15, 1930, at the Post Office at Easton, Pa., under the Act of March 3, 1879.

See p. 348 for Technical Committees

A 13.6-MM. SUPER-HIGH-INTENSITY CARBON FOR PROJECTION*

D. B. JOY**

Summary.—*A new 13.6-mm. super-high-intensity carbon is described which will burn at currents as high as 190 amperes and which has a higher intrinsic brilliancy and a more uniform distribution of light across the crater face than the regular 13.6-mm. carbon rated at 120 to 130 amperes.*

Tests comparing the light projected upon a projection screen by this new carbon and by the regular carbon show conclusively that the available light has been increased by at least 30 per cent. The arc lamp used with the carbons must be properly designed to take care of the increased current and carbon consumption.

The regular 13.6-mm. high-intensity positive carbon burning at 120 to 130 amperes and used in the condenser type of high-intensity lamp has been the light-source used in the largest theaters of the country for a number of years. The increase in general theater lighting, the size of the picture, the size of the theater, and the anticipated use of color have caused demands from a number of theaters for a 13.6-mm. high-intensity carbon that will furnish more light than is available from this standard carbon.

In addition to this, in the last few years, background projection for process photography has been used extensively in motion picture studios. This process, which has been described by Popovici,[1] Harrison,[2] and others consists in projecting a picture of the desired background through a translucent screen and rephotographing this picture with foreground objects to give the final composite scene. Because of the light loss occurring through the screen a very large amount of light is desired. It is also essential that the light-source have a considerable range of intensity because of the difference in density of the films being projected. A further requirement is that there should be a minimum decrease of light at the sides of the picture.

It is therefore evident that both from the standpoint of projecting

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* Presented at the Spring, 1936, Meeting at Chicago, Ill.

** Laboratory, National Carbon Co., Inc., Fostoria, Ohio.

motion pictures and photographing motion pictures with projected backgrounds, it would be desirable to have available a light-source of the same dimensions as the present 13.6-mm. carbon but capable of giving a considerably greater amount of light and a more uniform distribution across the projection screen.

The new super-high-intensity 13.6-mm. carbon has been designed to meet these requirements. It has the same outside diameter as the regular 13.6-mm. carbon but has a much larger core. Its design and composition are such that it will burn steadily at currents of 140 to 190 amperes. At the lower current the crater is comparatively shallow, but at the higher currents it is considerably deeper than that of the regular carbon.

The consumption of the carbon at various currents, compared with that of the regular 13.6-mm. carbon, is given in Table I. The maximum current-carrying capacity of the regular carbon is 130 amperes.

TABLE I

Consumption of Regular and Super 13.6-Mm. Carbons at Same Arc Setting

Carbon	Current	Voltage	Consumption (Inches per Hour)
Regular 13.6-mm.	120	64	11.3
Regular 13.6-mm.	130	68	15.5
Super 13.6-mm.	140	60	12.6
Super 13.6-mm.	160	66	18.0
Super 13.6-mm.	180	72	25.5

In contrast to this, the super-high-intensity carbon gives a very steady light at much higher currents and consumption rates than the regular carbon. It can be anticipated, because of the larger core size and higher consumption, that the intrinsic brilliancy would be both higher and more uniformly distributed across the crater face than in the case of the regular 13.6-mm. carbon.

Measurements of the intrinsic brilliancy across the crater face are given in Fig. 1. The curves show that at 180 amperes the intrinsic brilliancy of the super-carbon crater is noticeably higher than that of the regular carbon crater at its maximum current of 130 amperes. It is also evident that with the super-carbon the tapering of the intrinsic brilliancy from the center to the sides of the crater is less. For example, at a distance of 3 millimeters from the center, the

intrinsic brilliancy compared with the brilliancy at the center has decreased to 69 per cent for the regular carbon at 130 amperes, but only to 82 per cent for the super-carbon at 180 amperes. This flatness of the intrinsic brilliancy curve of this new carbon is accentuated at the lower current densities. At 160 amperes the intrinsic brilliancy at the center of the crater is a little lower than that of the regular carbon at 130 amperes, but is considerably higher at the sides of the crater. The total crater diameter increases with increasing current.

The significance of this difference in the intrinsic brilliancy distribution becomes apparent upon comparing magnified images of the

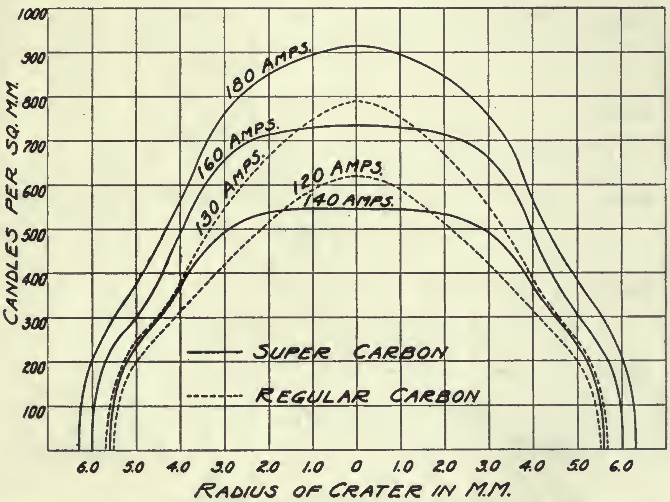

FIG. 1. Distribution of intrinsic brilliancy across crater face of regular and super 13.6-mm. high-intensity carbons.

crater face of the regular carbon and of the super-carbon. With the regular carbon there is a noticeable change in the color of the light near the edge of the crater, where the incandescent shell is the predominating light-giving material. With the super-carbon, apparently, the incandescent gases fill the crater more completely, resulting in much less change of color near the edge of the crater and a greater diameter where the gases themselves form the principal source of light.

These intrinsic brilliancy curves indicate that the new carbon when burned at its rated current should give a higher light and more uni-

form light upon the projection screen than the present carbon. This is more apparent if the amount of light is calculated for given areas of the heart or central portion of the crater. This comparison is given in Fig. 2, which shows the total candle-power emitted directly in front of the arc for the various central areas of the crater. For example, if an area at the heart of the crater of 8 millimeters in diameter is considered, the candle-power emission for the regular 13.6-mm. carbon at 130 amperes is 28,700 and for the super-carbon at 180 amperes is 38,400. If an optical system utilizes this area it means that the light through the optical system would be proportional to the candle-

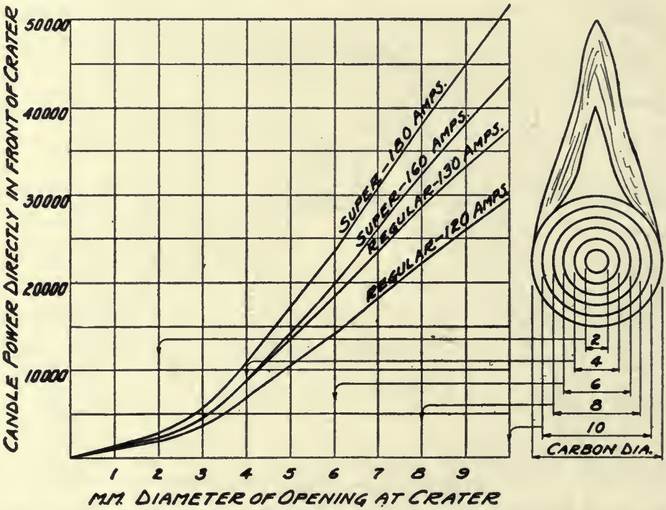

FIG. 2. Candle-power directly in front of arc, of central areas of crater of regular and super 13.6-mm. high-intensity carbons.

power, or about 34 per cent greater for the super-carbon. The light upon the screen from the regular and the super-high-intensity 13.6-mm. carbons was measured by means of the optical system shown in Fig. 3*a*. This system consists of the regular or super-carbon, a pair of condensing lenses, a standard sound aperture plate, and a $5^1/_2$-inch, $f/2.5$ objective lens. The condensers were designed to give an elliptical shape to the spot on the aperture plate. A shutter was not used in the system.

The position of burning of the carbons is shown in Fig. 3*b*. The same burning position was used in all tests with this optical system

in order to avoid any difference[3] in light or light distribution caused by a change in either the position of the carbons or the arc flames. The light upon the projection screen was measured by means of Weston photronic cells corrected by means of a green screen to approximate the sensitivity of the eye. These cells were placed at the positions shown in Fig. 3*c*. The cells at the sides and corners were placed at the edges of the light zone; and their readings, compared with the reading of the center cell, give a true picture of the decrease in the light from the center to the sides or corners of the screen.

Preliminary measurements showed that the super-carbons give an increase in light when the positive carbon is held at exactly the same position with respect to the optical system, and also tend to

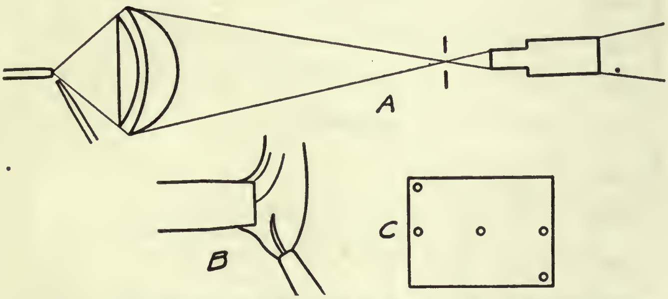

FIG. 3. (*a*) Optical system used in tests; (*b*) positions of carbons and arc; (*c*) location of phototronic cells on projection screen.

build up the light at the sides of the screen. This, of course, would be anticipated from the shape of the intrinsic brilliancy curves. In order to place the measurements upon a common basis, it was decided to take a series of readings of the screen light, moving the lenses with respect to the aperture plate and carbons. By this method the distribution of light falling upon the projection screen could be varied over a considerable range, and the light from the two types of carbon could be compared directly for the same light distribution. Screen light measurements were made of the regular carbon at 120 and 130 amperes and of the super-carbon at 160 and 180 amperes. These measurements were all grouped according to the light distribution upon the screen and were then plotted as shown in Fig. 4.

In this figure the total lumens projected to the screen are plotted

against the distribution. This gives a direct comparison of the amount of light obtained from these carbons at the various currents and for the distributions noted in the figure. For example, for a distribution factor from the center to the sides of 80 per cent, and from the center to the corners of 60 per cent, the regular carbon at 130 amperes provides 5700 lumens on the screen and the super-carbon at 180 amperes 7500 lumens. These values, and, to some extent, the distribution of the light, depend upon the design of the optical system[4, 5, 6] as well as upon the light from the arc; but

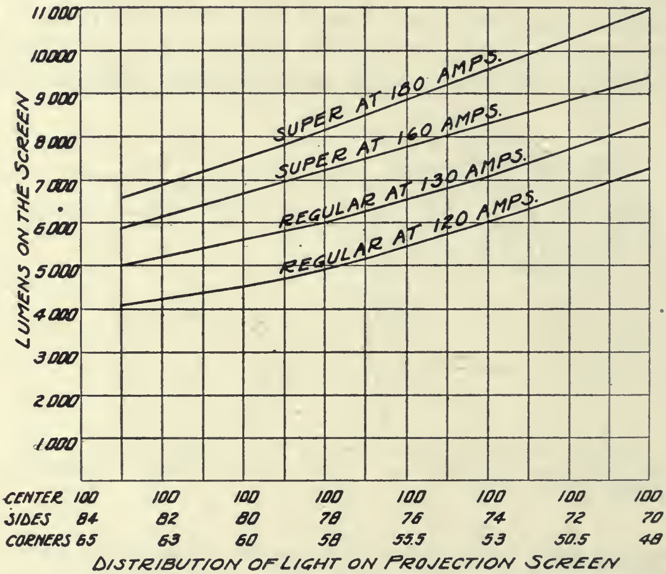

FIG. 4. Light on projection screen for various distributions of the light (shutter of optical system not running).

since the same optical system was used for all these measurements, the figures are directly comparable. It is evident that the super-carbon at either 160 or 180 amperes affords a distinct increase in light over the regular carbon at its highest rated current of 130 amperes. This advantage holds for the light distributions commonly encountered.

These data emphasize the necessity of making comparative measurements upon the basis of the same light distribution on the screen. The effect of the distribution is better illustrated by Fig. 5 which

shows the foot-candle readings on a screen 15 × 20 ft. for the super-carbon at 180 amperes, for various light distributions with the optical system that has been described. The foot-candles are plotted against the distance from the center of the screen as illustrated by the diagram in the lower right-hand corner. For a distribution factor of 80 per cent at the sides of the screen, values are shown of 30 foot-candles at the center, 24 at the sides, and 18 foot-candles at the corners. If the distribution factor is 72 per cent at the sides, the

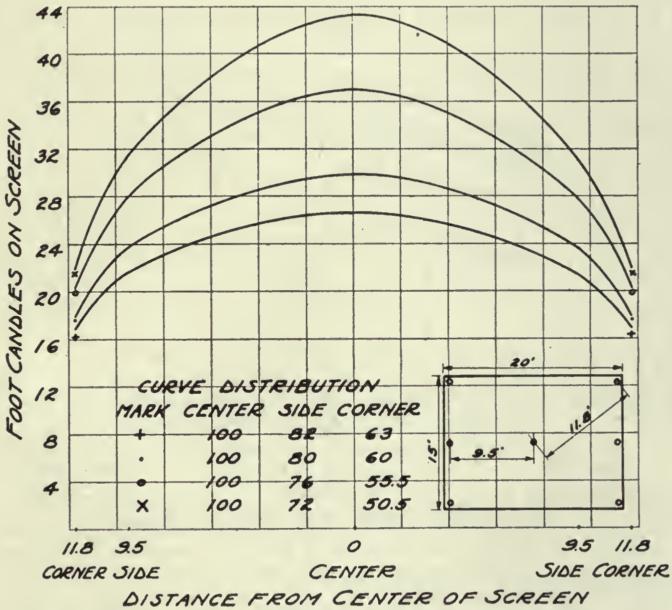

FIG. 5. Effect of light distribution upon foot-candle reading on 15 × 20-ft. projection screen (shutter of optical system not running).

foot-candle reading at the center is 43, at the sides 31, and at the corners 22, and the total lumens upon the screen are increased from 7500 to 10,300. Cook[4] and Rayton[5] have pointed out that the effect of the complete optical system, when adjusted to give maximum light output, is to emphasize the contrast in intensity between the center and the edges of the screen. It is possible, however, by readjusting the focus, to compensate for this effect so that the light at the sides and corners is satisfactory. It is evident from Fig. 4 that for the light distributions actually measured in these tests the maxi-

mum light had not been obtained. However, the curves do cover the range used in actual projection, particularly at the left-hand portion of the figure. A decrease of light to 80 per cent at the sides of the screen is not uncommon. Fig. 6 and Table II show a comparison of the foot-candle readings and lumens on a 15 × 20-ft. screen for the same screen light distribution for the regular and the super-high-intensity carbons. These foot-candle readings as well as the total lumens again show definitely the gain in light made possible by the super-carbons.

If it is desired to build up the light at the sides and the corners of

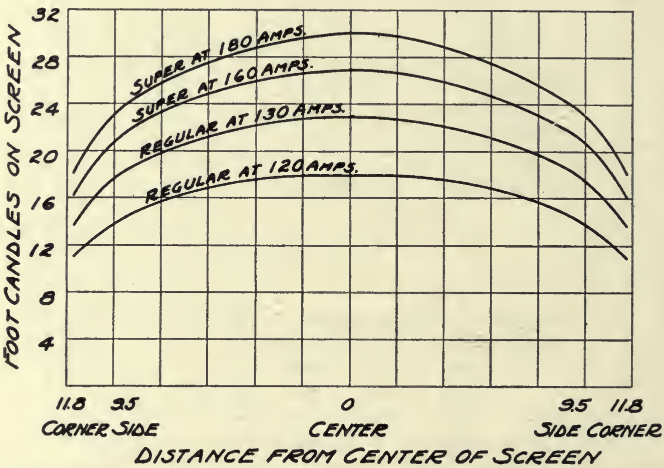

FIG. 6. Foot-candle readings on 15 × 20-ft. screen for distribution factor of 100 at center, 80 at sides, and 60 at corners (shutter of optical system not running).

the screen, compared with the center, it can be done by means of this super-carbon. For example, by proper focusing and with the same optical system, the super-carbon at 180 amperes will project the same amount of light to the center of the screen, but approximately 10 per cent more light to the sides and 20 per cent more to the corners, than the regular carbon at 130 amperes.

From the foregoing intrinsic brilliancy curves and comparisons on the screen with a conventional optical system, it is evident that the super-carbon will provide at least 30 per cent more light than the regular carbon for the same screen light distribution. In order to utilize the new carbon to the best advantage the lamp must be cap-

able of withstanding the high currents, and the feeding mechanism must feed the carbons uniformly at the rates indicated in Table I.

The more uniform intrinsic brilliancy distribution across the crater face of the super-carbon may make it possible to use an optical system having lower magnification and still obtain an even greater increase in light than has been obtained with the optical system used in this work. This has been approximated to a limited extent in the tests summarized in Fig. 4 by moving the lenses so as to give the same light distribution for the regular carbon and the super-carbon.

TABLE II

Total Lumens on Screen for Light Distribution of 80 Per Cent at Sides and 60 Per Cent at Corners

(*No Shutter Running*)

Carbon	Current	Lumens	Per Cent Lumens
Regular 13.6-mm.	120	4550	100
Regular 13.6-mm.	130	5700	125
Super 13.6-mm.	160	6750	148
Super 13.6-mm.	180	7500	165

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DISCUSSION

MR. BRENKERT: How much would you have to adjust the optical system to reduce the light from the super-carbon to what is supplied by the regular carbon? What is the effect at the center of the screen?

MR. JOY: Referring to Fig. 4, when adjusting for equal distribution the screen lumens for both the regular and the super-carbon will fall upon the same vertical line. The super-carbon must be moved about 0.1 inch farther from the lens to

obtain the same ratio of light at the sides to light at the center of the screen; that is, the same distribution.

If the carbons were burned in exactly the same position, the super-carbon might have a distribution factor of, say, 100 at the center and 80 at the sides of the screen, while the regular carbon would give factors of 100 at the center and 74 at the sides. If the super-carbon is moved from the lens until the same distribution of light occurs on the screen as with the regular carbon in the original position, the amount of light will be greater, as shown in Fig. 4.

Mr. Brenkert: If you have a reading at the corners of the screen of, for example, 14 foot-candles for the regular carbon, and adjust the super-carbon to produce at least the same reading at the corners, what would be the reading at the center?

Mr. Joy: It would increase by considerably more than 30 per cent; perhaps 40 or 50.

Mr. Brenkert: Was that actually demonstrated by the same optical system?

Mr. Joy: Yes. Assume that we have a ratio of light at the center to light at the sides of 100 to 80, as is the case in Fig. 6. The regular carbon at 130 amperes with a given optical system on a 20-ft. screen gives 23 foot-candles at the center and 18 at the sides; whereas the super-carbon at 180 amperes and moved slightly back from the rear condenser to give the same distribution with this optical system, gives 30 foot-candles at the center and 24 at the sides, and the total light increase is 30 per cent.

If we move the super-carbon toward the rear condenser, the light at the center and at the sides of the screen will decrease, faster at the center than at the sides, and the distribution will become even flatter. If, on the other hand, we move the super-carbon farther from the rear condenser, the light at the sides and the center increases, again faster at the center than at the sides, at least in the range that we investigated as shown by Figs. 4 and 5. For example, with the super-carbon moved back so that the distribution factor at the sides is 76, the foot-candle reading is 37 at the center and 28 at the sides, or an increase of 50 to 60 per cent over the regular carbon at 130 amperes and for a different light distribution.

PRESENT TRENDS IN THE APPLICATION OF THE CARBON ARC TO THE MOTION PICTURE INDUSTRY*

W. C. KALB**

Summary.—*The present trend in the motion picture industry is toward more extensive use of the high-intensity carbon arc in both the theater and the studio. From the earliest days, progress in the industry has been attended by constant demands for more light and for light of better quality. The high-intensity arc is the most effective means of satisfying these demands, and promises in a short time to dominate the field of theater projection and to extend its field of application in studio lighting.*

PROJECTION

The necessity for using, in projection, a light-source of very high intrinsic brilliancy is illustrated by the following example. A screen image 20 feet wide is 90,000 times the area of the 0.800-inch aperture through which the light is projected, and with a magnification of 6:1 from the crater to the aperture, is 3,240,000 times the area of that portion of the light-source focused within the aperture limits. Disregarding all losses in pick-up and transmission, an intensity of 10 foot-candles incident upon the screen calls for a brightness of 111 candles/mm.^{2} at the source. A 120-degree mirror picks up only about 75 per cent of the total light emitted by the source. Losses through the film and the lens further reduce the intensity of illumination of the screen. It is therefore obvious that screen sizes now in use have gone well beyond the limit at which the low-intensity arc with a maximum intrinsic brilliancy of 175 candles/mm.^{2} can provide a satisfactory level of screen illumination.

Low-Intensity Arcs.—The properties of the low-intensity reflecting arc have been discussed in this JOURNAL by Joy and Downes.[1] There is a definite limit both to the intrinsic brilliancy and to the whiteness of the light available from this source, fixed by the subliming temperature of carbon. Dr. Chaney and his associates[2] have determined the

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* Presented at the Spring, 1936, Meeting at Chicago, Ill.

** National Carbon Company, Inc., Carbon Sales Division, Cleveland, Ohio.

maximum brightness temperature of the positive crater of the carbon arc as being approximately 3810°K., and their findings have been confirmed by other investigators. Fig. 1 shows the energy distribution curve of the low-intensity carbon arc operated with 12-mm. positive and 8-mm. negative carbons at 30 amperes, 55 volts, d-c.; and, for comparison, the theoretical curve of black body radiation at 3810°K. It is apparent from these curves that, with the exception of the peaks at approximately 2500 and 3900 Å, which are characteristic of all carbon arcs, the energy distribution from this arc is a close approximation to the theoretical limit. The maximum intrinsic brilliancy under the conditions defined is slightly less than 175 candles/mm.[2]

High-Intensity Arcs.—The high-intensity arc is not subject to the same limitations as the low-intensity arc. Introduced to the motion picture industry more than 15 years ago, it has been described and its characteristics discussed in several papers in this Journal.[3,4,5] The high-intensity arc is operated at much higher current-densities in the electrodes than is the low-intensity arc. The positive carbon burns with a deep crater and is provided with a central core containing rare-earth minerals. The vapors from this core, confined by the arc stream to the cup-like crater, attain a brilliancy far greater than that associated with the temperature at which carbon sublimes. The result is a snow-white light and a crater brilliancy much higher than that attainable in the low-intensity arc. In the larger high-intensity arcs, the brilliancy of the crater exceeds 800 candles/mm.[2] From Fig. 2, which shows the energy distribution of a typical high-intensity arc, it is evident that the colors are more evenly balanced and the light consequently whiter than that of the low-intensity arc.

The larger theaters were prompt to make use of the greater volume and improved quality of light that the high-intensity arc provided. However, its use for projection in small theaters was not practicable, from an economic standpoint, up to 3 or 4 years ago. The first important extension of the high-intensity principle of arc operation came with the development of the a-c. high-intensity carbon,[6,7,8] which was shortly followed by the Suprex carbon[9]—a similar carbon designed for direct current. Both these new carbons are copper coated and of smaller diameter than the carbons previously used in high-intensity arcs. They are operated without being rotated, and are gripped at a point remote from the arc. Prompt development of

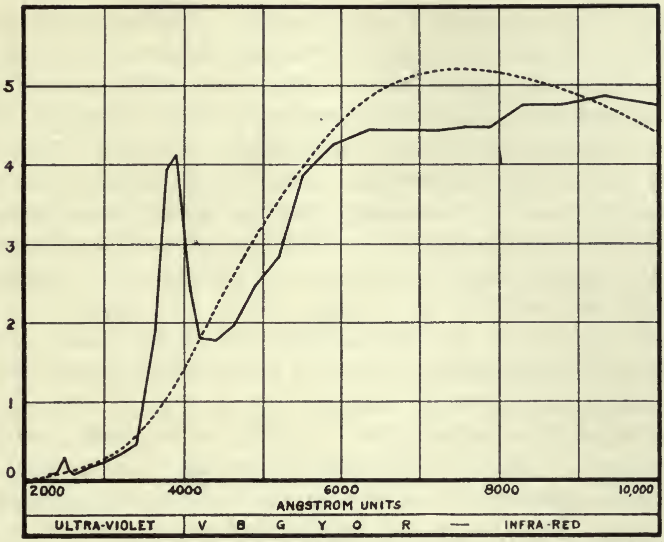

FIG. 1. Energy distribution from low-intensity arc: (*solid line*) 30-ampere, 55-volt, d-c. arc; 12-mm. positive carbon; (*dotted line*) radiation curve of theoretical black body at 3810°K.

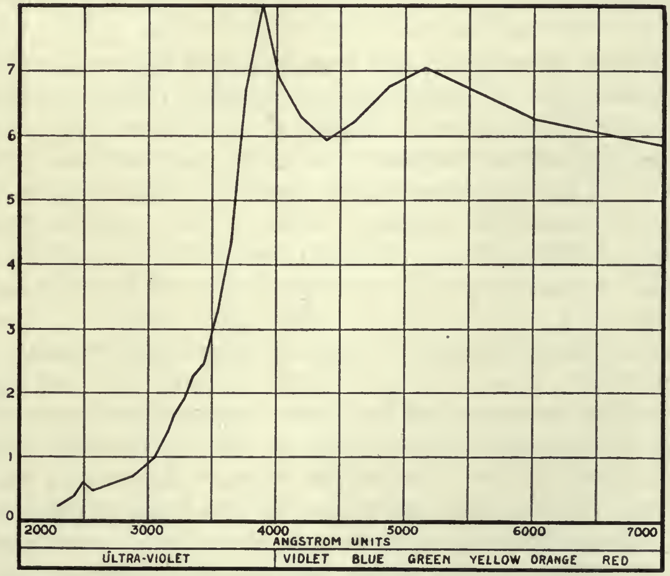

FIG. 2. Energy distribution from high-intensity arc: 125-ampere, 63-volt, d-c. arc; 13.6-mm. positive carbon.

lamps for their use placed high-intensity light-sources for the first time within the economic reach of the small theater.

Advantages of High-Intensity Projection.—The experience of theaters that have used high-intensity projection has demonstrated that it possesses two distinct advantages. First, the snow-white quality of the screen illumination has proved much more pleasing to the audience than the somewhat yellow tint characteristic of the low-intensity arc. Second, the higher level of general illumination permitted by the increased screen brightness adds greatly to the comfort of the patrons entering the theater. These advantages are rapidly extending the use of the high-intensity arc in the smaller theaters, displacing the low-intensity, reflecting arc which, in recent years, has practically monopolized this field.

The Super-High-Intensity Arc.—For some time there has been a demand by a number of the larger theaters for still greater screen illumination than can be supplied by the 13.6-mm. high-intensity arc operated at 120–130 amperes. Screens well over 40 feet wide are now being used in some theaters. Since the intensity of screen illumination from a given volume of projected light varies inversely as the square of the image width, it is apparent, from the example cited earlier, that these large screens require a light-source of tremendous power.

This latest demand for more projection light has been met by the development of a 13.6-mm. super-high-intensity carbon, described by D. B. Joy.[10] This carbon is adapted to steady operation over a current range of 140 to 190 amperes. At the upper range of current it provides 30 per cent more light than the regular 13.6-mm. high-intensity carbon at 130 amperes. There is also a more uniform distribution of brilliancy over the crater face of the new carbon, with a resultant improvement in the distribution of light upon the screen.

Improvements in Lamps.—In addition to the improvements in carbon electrodes, there have been notable improvements in projection lamp design during the last few years. Among these are improved feeding mechanisms, closer control of the arc position, magnetic stabilization of the arc stream, and increase in light pick-up. Old type low-intensity lamps pick up a cone of illumination about 45 degrees in extent. The low-intensity reflecting arc increased the angle of collection to 106 to 120 degrees. Reflecting types of high-intensity arc use mirrors having collection angles of 95 to 122, and

condenser types, 69 to 79 degrees. The smaller angles of pick-up in the latter are to some extent compensated by lower ratios of magnification. The latest lamps, designed for the new a-c. high-intensity and Suprex carbons are using mirrors picking up light over angles as great as 145 degrees. The optics of projection place limits upon the extent to which this trend toward greater angles of pick-up can be carried. The improvements that have been made, however, have been a substantial factor in making higher intensities of screen illumination available.

STUDIO LIGHT

In the field of production, as well as in projection, substantial progress is being made in adapting the carbon arc to present needs. The development of the studio carbon arc, using metal-coated white-flame carbons, has already been discussed.[11, 12] Although essentially a flame type of arc, the broadside studio arc is operated under conditions quite different from those applying to the regular white-flame photographic carbon arc. The improved lamp design eliminates all lamp noises and fulfills every demand of sound picture production. At the usual operating current of 35 to 45 amperes, the $^1/_2$-inch regular white-flame photographic carbon carries a current-density of 180 to 200 amps./in.^{2}, whereas the current-density in the metal-coated carbons of the studio arc at 35 to 40 amperes is 450 to 515 amps./in.^{2}. This is comparable to the current-density in many high-intensity arcs. While this new studio arc can not be defined as a high-intensity arc, because it lacks the well defined crater and the characteristic gas-ball of the latter, the character of the light emitted differs materially from that of the regular white-flame carbon, as may be seen in Fig. 3. In quality of light this studio arc has many of the characteristics of the high-intensity arc. Its photographic effectiveness and its excellent color balance for monochromatic as well as for color productions have been discussed in papers by Bowditch and Downes.[13, 14]

Sun arcs and rotary spots using the high-intensity arc have been greatly improved to adapt them to the sound stage. A new high-intensity rotary spot of compact design[15] combines the ideal beam characteristic of the condenser type lamps with the high power of the reflecting arcs. By means of an improved optical design, which includes the use of a modified Fresnel type of condensing lens, this lamp makes use of a much higher percentage of the total light from the

source than the older condenser lens designs. This design entirely eliminates the often-troublesome shadow of the negative carbon and its support, and provides a range of beam-spread from a 4-degree spot beam to a 44-degree flood, without dark spot or rings. Regardless of spread, the highest intensity of the beam is always at the center, falling off smoothly toward the edges. Such a beam can very easily be blended with the beams from adjacent lamps. The carbons are fed continuously, maintaining uniform arc voltage and arc gap, so that the arc burns without change of intensity or color. The

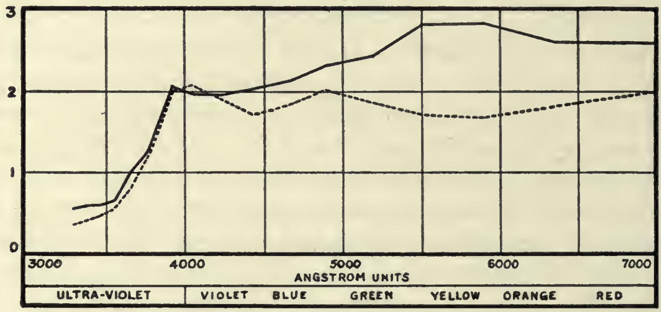

FIG. 3. Energy distribution from photographic carbons: (*full line*) 8-mm. metal-coated white-flame studio carbons, 40 amperes, 37.5 volts d-c.; (*dotted line*) 13-mm. regular white-flame photographic carbons, 35-amperes, 37.5 volts d-c.

carbon-feeding mechanism has been made sufficiently silent to permit operating the lamps at normal speed within 10 feet of the microphones.

The new super-high-intensity arc is rapidly finding application in the studio for background projection, in which the increased volume of illumination is of distinct advantage. There is further advantage in the wide range of current over which steady operation obtains, permitting adjustment of the projection light to compensate for a wide variation of density in the film projected upon the background screen. Upon the basis of increased light output, as well as perfect color balance of the light, the adaptation of the super-high-intensity arc to stage illumination in motion picture production likewise seems to be indicated.

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COLOR QUALITY OF LIGHT OF INCANDESCENT LAMPS*

R. E. FARNHAM AND R. E. WORSTELL**

Summary.—*The advantages of concentrating the source of gas-filled incandescent lamps are discussed, and the various forms available and their application to optical systems and reflectors are shown.*

Data regarding the temperature (color and maximum) of the various types of lamps are presented, and the similarity of the radiation of incandescent lamps to that of a Planckian radiator of suitable temperature is indicated. Curves showing the amount of light emitted at various wavelengths or colors for all lamps of interest to the motion picture industry are presented, in terms of both equal visual output and equal wattage. A discussion of the energy in the ultraviolet region and the effect of glass bulbs and lenses concludes the paper.

Years ago the color quality of light was of no importance in most motion picture photography. With the old orthochromatic emulsions, light-sources of radically different color characteristics were mixed indiscriminately upon a set. With the introduction of panchromatic film sensitive to all wavelengths in the visible spectrum, some attention[1] began to be paid to the color characteristics of the light-source. Today, with the diversity of types of "black-and-white" emulsions, the ever-increasing use of color photography, the recognition of ultraviolet light in some applications, and the complexity of processing methods, the spectral energy characteristics of light-sources employed in the industry are of vital importance.

Much has been published in various scientific and research journals regarding the spectral energy distribution of incandescent lamps. However, the data are abstruse, and it is therefore the purpose of this paper to present the subject in a form readily usable by motion picture engineers.

Extensive researches by Forsythe, Worthing,[2] and others have shown that the radiation from an incandescent tungsten source is continuous from the near ultraviolet, through the visible portion of the spectrum, and well into the infrared region. They have found

* Presented at the Spring, 1936, Meeting at Chicago, Ill.

** General Electric Co., Nela Park, Cleveland, Ohio.

also that it follows very closely the radiation characteristics of the hypothetical black body or Planckian radiator. If the temperature of an incandescent lamp is known, the black body radiation curve for that temperature as determined by Planck's formula shows fairly accurately the energy distribution of the lamp. Temperature measurements of lamp filaments are generally given either as "maximum" or "average." The maximum temperature is usually midway between the supports and at the center coils. Support and lead-in wires produce cooler zones in several turns of the coil either side of the point where they contact the filament. Forsythe has found, however, that for the majority of filament constructions employed in lamps in the 110–120-volt range, the maximum temperature corresponds very closely to the color temperature; sufficiently so that the values of maximum temperature may be used in choosing the Planck radiation curve.[3] Table I gives the maximum true temperatures in degrees Kelvin of a number of typical lamps of interest to the motion picture industry.

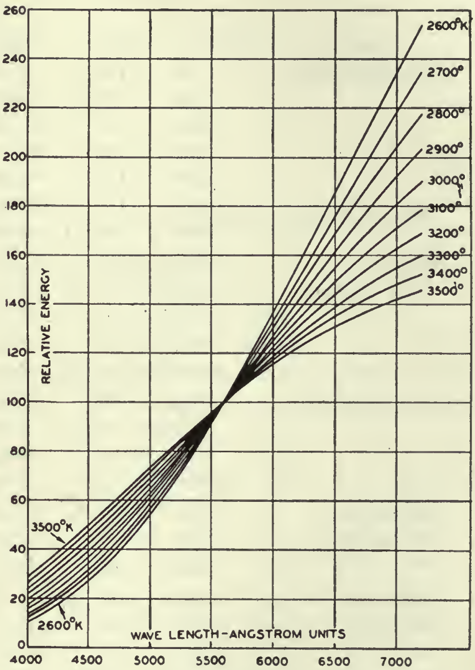

FIG. 1. Spectral energy distribution in the visible region from tungsten filaments drawn arbitrarily for equal radiation intensities at wavelength 5600 Å.

The curves of Fig. 1 show the spectral energy distribution for color temperatures ranging from 2600° to 3500°K. These are representative of a series of lamps operating at the temperatures indicated, and have been drawn in the conventional manner through a common point, *viz.*, 100 per cent relative energy at 5600 Å. These data are presented in 100-degree steps rather than for each lamp temperature, which in

some cases changes by only 5°, to avoid confusion arising from crowding the curves at the shorter wavelengths. To obtain the energy distribution in the visible spectrum of any of the lamps listed

TABLE I

Maximum True Temperatures of Several Types of Incandescent Lamp

Lamps	Watts	Volts	Bulb	Efficiency (Lumens/-Watt)	Rated Av. Life (Hrs.)	Maximum True Temperature (Degrees K.)
General Service	60	115	*A-21*	12.5	1000	2755
	100	115	*A-23*	15.2	750	2835
	200	115	*PS-30*	17.0	1000	2880
	300	115	*PS-35*	18.1	1000	2905
	500	115	*PS-40*	19.4	1000	2935
	1000	115	*PS-52*	20.7	1000	3000
	1500	115	*PS-52*	21.7	1000	3020
Studio	1000*MP*	115	*PS-52*	24.5	250	3130
Set Lighting	1500*MP*	115	*PS-52*	26.0	250	3180
	2000*MP*	115	*G-48*	27.5	100	3225
	5000*MP*	115	*G-64*	29.0	100	3280
	10000*MP*	115	*G-96*	29.5	100	3300
(Movieflood)	2000*CP*	115	*PS-52*	32.7	15	3380
	2000*CP*	115	*G-48*	32.7	25	3370
	5000*CP*	115	*G-64*	32.7	75	3370
	10000*CP*	115	*G-96*	32.7	75	3370
Projection	300	115	*T-10*	23.5	25	3230
(Monoplane)	500	115	*T-20*	26.3	50	3265
	900	30	*T-20*	26.5	100	3240
Projection	500	115	*T-10*	25.0	25	3295
(Biplane)	750	115	*T-12*	26.0	25	3255
	1000	115	*T-20*	27.6	25	3260
Photocell	7.5 amps.	10				3165
Exciter	4.0 amps.	8.5				3060
Photoflood No. *1*	250	115	*A-21*	33.5	2	3490
Photoflood No. *2*	500	115	*A-25*	33.5	6	3430
Photoflood No. *4*	1000	115	*PS-35*	33.5	10	3410
Photoflash						3500*

in Table I it is necessary merely to interpolate between the two curves of temperature in Fig. 1 nearest the temperature of the lamp in question.

As the efficiency of a filament is raised or lowered, the temperature changes accordingly, as does the light output and wattage. It is also true in the case of lamps of equal wattage that the light emitted

* Average color temperature.

varies in quantity as well as in color quality, depending upon the filament temperature. To illustrate, in Fig. 2 are shown the spectral distributions of energy in the infrared, visible, and ultraviolet regions

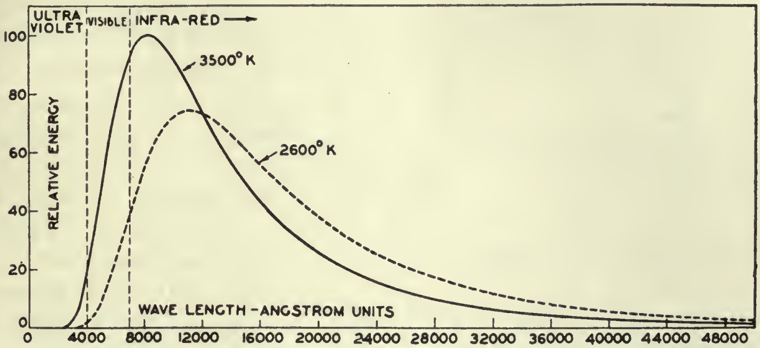

FIG. 2. Total spectral energy distribution from tungsten filaments of equal wattage but different temperatures.

emitted by two tungsten filaments at 3500° and 2600°K., as computed by Holladay[4] from data on Planckian radiators. Each filament consumed the same wattage, and the two filaments therefore were radiating equal total energy. It will be observed that as the temperature increases so does the percentage of total radiation emitted in the visible and ultraviolet, with some decrease in the infrared. It is also apparent that radiation at the shorter wavelengths has increased in greater percentage than that at the longer wavelengths below 7000 Å, thereby resulting in a color change. In Fig. 3 the visible region of Fig. 2 has been shown to a larger scale, and for

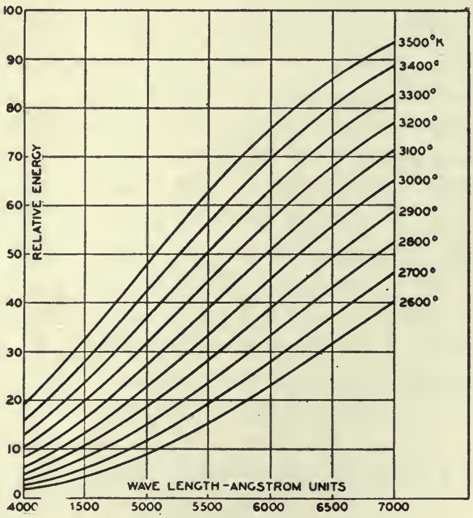

FIG. 3. Spectral energy distribution in the visible region from tungsten filaments of equal wattage but different temperatures.

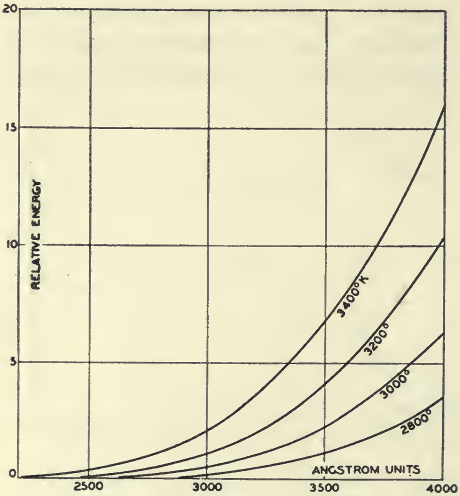

FIG. 4. Spectral energy distribution in the ultraviolet from tungsten filaments of equal wattage but different temperatures.

purposes of comparison, curves at 100°K. intervals have been included.

Due to recent developments in recording sound it is of importance to study the amount of energy emitted in the ultraviolet by incandescent lamps at several temperatures. These data are presented in Fig. 4 with no allowance made for the transmission of the bulb glass in the near ultraviolet. Fig. 5* gives the transmission characteristics in the ultraviolet region for three commonly used types of bulb glass. Fig. 6 presents the data of Fig. 4 corrected for the transmission characteristics of lime glass such as is used for the Photoflood and Movieflood lamps. Since similar data for lead glass vary less than the width of the line in the chart from those given for lime glass, Fig. 6 is applicable to lead glass as well. Similarly, Fig. 7 shows the data for Pyrex glass as used with the 2-, 5-, and 10-kw. lamps employed for motion picture studio photography. Attention is called to the fact that Fig. 4 is plotted to an ordinate scale

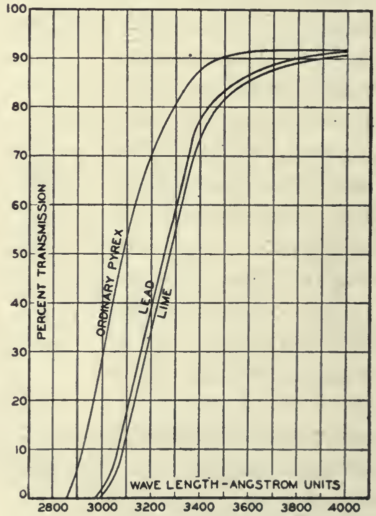

FIG. 5. Transmission per millimeter of thickness of three types of glass in the ultraviolet.

* Data from B. T. Barnes, Lamp Development Laboratory, General Electric Company, Nela Park, Cleveland, Ohio.

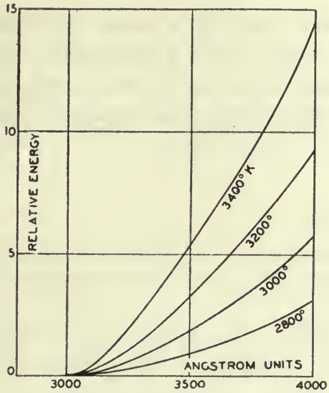

FIG. 6. Spectral energy distribution in the ultraviolet from tungsten filaments of equal wattage but different temperatures, through lime glass 1 mm. thick.

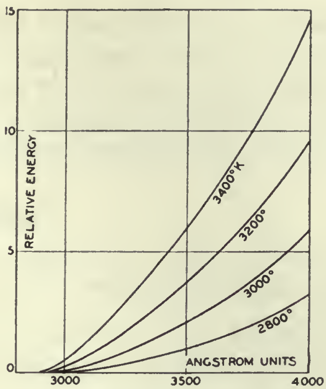

FIG. 7. Spectral energy distribution in the ultraviolet from tungsten filaments of equal wattage but different temperatures, through Pyrex glass 1 mm. thick.

five times more open and an abscissa scale two times that employed in Fig. 3. However, the numerical values of relative energy are directly comparable.

It has become quite common practice to use the No. *1* Photoflood lamp in conjunction with the standard *A*, *B*, and *5-C* tricolor filters for producing three-color separation negatives. Fig. 8 shows the relative radiant energy available in each color when each of the three filters is employed with the Photoflood lamp.

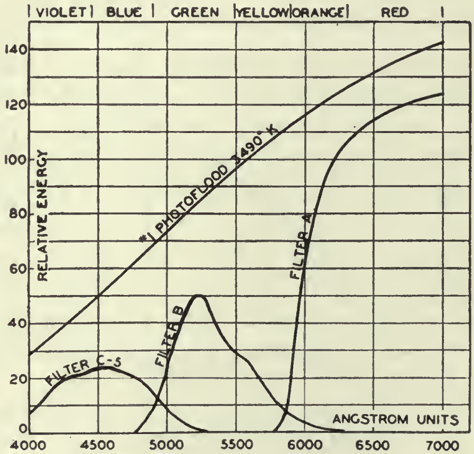

FIG. 8. Spectral energy distribution from Photoflood lamp No. *1*, transmitted through *A*, *B*, and *C-5* tricolor filters.

Color processes, such as Dufaycolor, Kodachrome, and Technicolor, require substantially white light for correct color reproduction. For these processes the correct color quality can be obtained by using Corning's Lunar

White No. *570* filter with a Photoflood lamp or a lamp operating at essentially the same color temperature as the Photoflood. The resulting light output from this combination is shown in Fig. 9. Libby-Owens-Ford medium-blue and Brigham's No. *26* gelatin produce practically the same result.

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[2] FORSYTHE, W. E., AND WORTHINGTON, A. G.: "The Properties of Tungsten and the Characteristics of Tungsten Lamps," *Astrophy. J.*, **LXII** (April, 1925), No. 3, p. 146.

[3] Miscellaneous Publication No. 56, *U. S. Bureau of Standards*, Washington, D. C.

[4] HOLLADAY, L. L.: "Proportion of Energy Radiated by Incandescent Solids in Various Spectral Regions," *J. Opt. Soc. Amer. and Rev. Sci. Instr.*, **17** (Nov., 1928), No. 5, p. 329.

DISCUSSION

MR. MILI: The authors show a table giving the maximum temperature of various incandescent filament lamps. In addition, a temperature of 3500°K. is given for the photoflash lamp. While it is true that the color temperature of an incandescent tungsten lamp is about the same as the maximum temperature, this is not true for the photoflash lamp. According to the latest tests, 3500°K. is the average color temperature of the photoflash throughout the whole cycle of the flash, and not the maximum temperature, which is doubtless much higher.

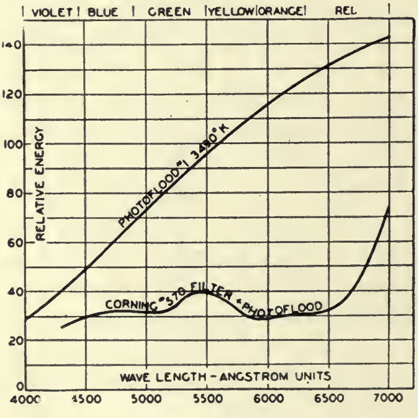

FIG. 9. Spectral energy distribution from Photoflood lamp No. *1*, transmitted through Corning Lunar-White No. *570* filter.

MR. WORSTELL: Mr. Mili is correct. The color-temperature shown for the photoflash lamp is an average and not a maximum value. The maximum color temperature occurs when the flash reaches its peak. Since the peak endures for only a few thousandths of a second, the color temperature at this point is very difficult to obtain. I know of no one who has determined it.

ACOUSTIC CONSIDERATIONS IN THE CONSTRUCTION AND USE OF SOUND STAGES*

D. P. LOYE**

Summary.—*Sound insulated stages are required for the production of sound pictures. Stages required to house a number of sets should be made acoustically dead. Stages consisting of only one set, such as scoring stages used for recording music, should have acoustical characteristics comparable to those of the concert hall.*

A scoring stage should not only have the proper reverberation time-frequency characteristic but, in addition, the wall and ceiling surfaces should be broken up in order to diffuse the sound. Measurements made on a stage where sound reflection from the floor was not prevented indicated the effect upon the frequency characteristic of a prominent first reflection.

The use of more than one microphone for pick-up may lead to difficulties comparable to those experienced with stages having prominent reflection. Characteristic charts showing these effects are discussed in the paper. Rules, based upon the preliminary experimental work described, are given for avoiding poor quality where it is deemed necessary to use more than one microphone for pick-up.

Before the days of sound recording, the director supervised the actions of his cast by means of a megaphone. The stages upon which he operated were regarded as satisfactory if they were rain-proof. The noise of the arc lights did not interfere with making the picture. To soothe the nerves of actors and actresses, offstage orchestras were often employed.

Upon the introduction of sound, the technic was of necessity changed, and sound-proof stages were constructed. The director was forced to abandon the megaphone, the lights were required to be noiseless, and offstage music could no longer be used. Part of the need for the orchestra was obviated by eliminating the extraneous noises that formerly had served to annoy the actors and actresses.

STAGE INSULATION

Some of the first sound stages to be constructed were expensive. Neither the required insulation nor the exact design data for obtain-

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* Presented at the Spring, 1936, Meeting at Chicago, Ill.

** Electrical Research Products, Inc., Hollywood, Calif.

ing specific degrees of insulation were known. Heavy double-wall construction was adopted, the stages consisting essentially of a room within a room, the inner structure being isolated as completely as possible from the outer. Studies and experience have indicated that by properly balancing the studio traffic and the cost of the stage construction, sound pictures can be recorded economically on stages that are appreciably less expensive than those originally built. It is still necessary in many instances to provide double-walled stages, but lighter materials are now employed and the cost of construction is appreciably less than originally. By properly combining the various kinds of acoustic materials, high insulation can still be attained when required.

A question that very naturally arises in connection with the construction of a sound stage is, how much insulation is required. The answer can be found by determining the maximum noise level that can be permitted within the stage, and the level of the outside noises, which must be prevented from disturbing the recording.

The maximum noise level permitted under the average conditions of recording in Hollywood studios is approximately 30 db. above the reference standard of 10^{-16} watts/cm.^{2}, as measured with a sound-level meter having a 30-db. equi-loudness contour weighting characteristic. A 1000-cycle tone having an intensity of zero db. is slightly lower than the threshold of audibility of the average ear. This maximum permissible level corresponds roughly to the noise of footsteps upon a carpet ten feet away, or to the noise produced by the average person when breathing, heard from a distance of two or three feet.

The noise levels that will exist outside the completed stage will, of course, vary somewhat with the particular studio conditions. If the stage is to be built at the edge of a studio lot, for instance, near a street upon which there is considerable traffic, the noise will be more severe and less subject to control than it would be if the stage were constructed near the center of the lot. Building a stage adjacent to a busy thoroughfare makes it necessary to provide greater insulation, involving heavier and more expensive construction.

Measurements recently made preparatory to building a new stage indicated that when the studio traffic was unrestricted, the noise intensity on the stage site ranged from 70 to 88 db. above the reference level. Inasmuch as traffic was subject to control during recording periods, the noise from a nearby woodworking mill having a maximal intensity at the stage site of 75 db. was the most important noise to

be excluded. To prevent this noise from reaching a value on the stage in excess of 30 db. above the reference level, the stage was required to have an insulation of 45 db. Measurements made following the completion of the stage indicated that the insulation adequately fulfilled this requirement.

The stage was of the double-wall type, the two wall sections being supported by separate studs. The floor and ceiling provided insulation consistent with that of the walls. Double doors, well sealed, were required to provide insulation in keeping with that provided by the walls. It was necessary to close both parts of each double door tightly in order to avoid leaks and maintain the proper noise reduction. Measurements indicated that failure to observe this precaution resulted in a marked increase in the noise in the portions of the stage adjacent to the doors. In order to prevent the transmission of traffic rumbles to the stage, the foundation was separated from the street pavement by a moat of soft earth and from ramps leading to the street by soft plastic filler.

STAGE REVERBERATION

Although proper acoustic insulation of sound stages is very important, it is not the only requirement. Satisfactory sound recording, for instance, could not be carried on in a barn-like stage even though the stage were well insulated. The reverberation would be too great. The question of what reverberation time-frequency characteristics should be provided can be answered by considering, first, the purposes that the stages serve.

Sound stages are generally used for housing a number of sets, each one representing a scene or scenes from portions of a picture. Inasmuch as the sets vary widely in character, it is reasonable to assume that the accompanying sounds would vary in acoustical quality. The most satisfactory recording conditions exist when the acoustical characteristics of the set are comparable to those of the room or other location in which the action is represented as taking place, some changes being necessary to allow for the present monaural character of the microphone pick-up technic. Sets depicting outdoor scenes should not be reverberant. A scene occurring in a small room can not be best recorded upon a stage having the reverberation of a large live room. It would have been quite unnatural if, in the picture *Skippy*, Jackie Cooper's bathroom monolog on the tyrannical practice of parents who insist that their little sons wash their teeth, had been re-

corded as if the action had taken place in Carnegie Hall. The illusion under such circumstances would not have been compatible with the private character of Skippy's tooth-brush-moistening act.

It is evident that a sound stage can not readily be made to provide the variety of acoustical effects appropriate to the various kinds of sets to be constructed upon it. The varying characteristics, if provided, must be contributed by the acoustical characteristics of the sets and by the placement of the microphone. It is therefore desirable that the stage be acoustically inconspicuous. In other words, the stage should be made as dead as possible; inasmuch as no part of it is seen in the completed picture, it should not be heard.

To accomplish this, it was common practice in constructing the original sound stages to fill the space between the studs with rock-wool. The thickness of the rock-wool fill ranged from 4 to 8 inches, depending upon the dimensions of the studs used in constructing the inner wall. The present recommended practice is to use either a 4-inch rock-wool fill, or a 2-inch rock-wool blanket over the studs, leaving an air space between the blanket and the surface behind it. Both the rock-wool fill and the 2-inch blanket over the studs provide good low-frequency absorption, which is desirable in order to guard against boominess on the stage. Stages so constructed have virtually flat reverberation time-frequency characteristics, the time throughout generally being less than one second.

The high absorption of the walls and ceiling, desirable for reducing stage reverberation to a minimum, also reduces the noise level of disturbances within the stage as well as those transmitted through the walls from the outside. The higher the acoustic absorption of the inner surfaces of the stage, the more completely will noises be eliminated.

SCORING STAGE CHARACTERISTICS

The stages that have been described so far are used for housing several sets. It is evident, however, that in some cases only one set is desired on a stage. In such instances the stage becomes the set, although the latter term is hardly applicable where photographing is not done. The most common form of single-set stage is the scoring stage used for making musical recordings. Such stages should be relatively live, rather than dead. They are often used for recording opera or other performances depicted as occurring in large theaters or concert halls. Scoring stages should, therefore, have acoustical characteristics comparable to those of the concert hall.

The optimal reverberation time for scoring stages employing the current recording methods has been discussed by Stanton and Schmid[1] in a paper in which are given data on the optimal reverberation time of broadcasting and recording studios as established by years of experience. The limits discussed by these authors are shown by the curves of Fig. 1.

In determining these optimal reverberation data, consideration was given to an important difference existing between listening conditions and present pick-up conditions of recording. It is an experimental

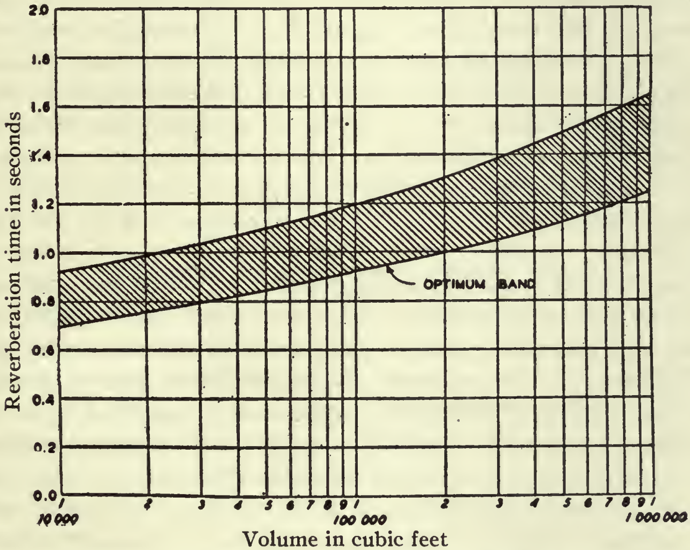

FIG. 1. Scoring stage optimal reverberation time.

fact that the loudness sensation is independent of the difference in phase between the sound pressures at the two ears of a listener. If, for instance, the two ears are stimulated by sound pressures of the same frequency, the loudness is the same regardless of whether the pressures are in or out of phase. As a result, the effects upon a normal listener of irregularities in the acoustic pattern of an auditorium are minimized, and, as Wente has pointed out,[2] the apparent liveness of the sound perceived by a listener is appreciably less than the recorded liveness. This effect can be observed by listening first with the two ears, and then observing the increase of apparent liveness that occurs when one ear is stopped. Inasmuch as the present recording technic

is monaural in character, even though multiple microphones may be used, scoring stages should be so designed and used that the liveness of musical recordings when reproduced under optimal conditions will be natural rather than accentuated. It is common practice to accomplish this by increasing the acoustic absorption in the scoring stage above what would be required for optimal direct listening conditions by placing the microphone closer to the orchestra than the listener would be located, and by distributing a major portion of the acoustic absorption at the end of the stage where the microphone is located.

The above-described limitations can be overcome to a large degree by stereophonic recording and reproduction. Such recordings involve the use of two separate recording channels, the two microphones used in picking up the sound being separated by an appreciable portion of the width of the auditorium. Reproduction requires the use of separate reproducer, amplifier, and loud speaker systems, the loud speakers being placed upon opposite sides of the stage. The details of the reproducing system used for direct musical reproduction have been fully described.[3]

Experimental stereophonic recordings were made by engineers of Electrical Research Products, Inc., during May and June of 1933, of organ, solo, and choir music in the Church of the Blessed Sacrament at Hollywood. Two separate microphones were placed above the audience section of the church, and separate equalized lines transmitted the music to two separate amplifier and recording systems at the test laboratory of Electrical Research Products, Inc. Reproduction of these recordings by means of two separate reproducer, amplifier, and loud speaker systems indicated the very marked improvement achieved by the method. Better "presence," depth, and a marked improvement in quality and naturalness were evident.

It is important to consider not only the optimal amount of acoustic treatment in designing a scoring stage, but also the most effectual distribution of the acoustic material. In a concert hall, the orchestra is surrounded by surfaces that tend to reflect the sound into the auditorium, thereby reinforcing the music in the audience area. The platform upon which the orchestra is seated usually is of wood. The surfaces surrounding the orchestra are therefore acoustically hard, making the stage relatively live. The audience area, on the other hand, is relatively dead. The carpeted floor, wall drapes, upholstered seats, and the audience itself, absorb sound. It is therefore reasonable to assume that the most natural and satisfactory acoustical conditions

will be found in scoring stages that are relatively live at the orchestra end and relatively dead at the end in which the microphone is placed. Experience has indicated that generally the most satisfactory recording conditions are provided by such an arrangement.

It is important also to consider a further design feature. The sound must be well broken up, or in other words, well diffused, in order to provide pleasing results. This is particularly true in recording where the advantages of binaural listening can not be completely utilized. Such diffusion reduces echoes and lessens the prominence of first reflections which, although they may not be recognizable as echoes due to the small time delay between them and the original sound, impair recording quality.

A method of accomplishing this diffusion may be illustrated by referring to one of the scoring stages recently constructed in Hollywood. Referring to Fig. 2, the design of the orchestra shell and the distribution of the acoustic treatment were in accordance with the following considerations:

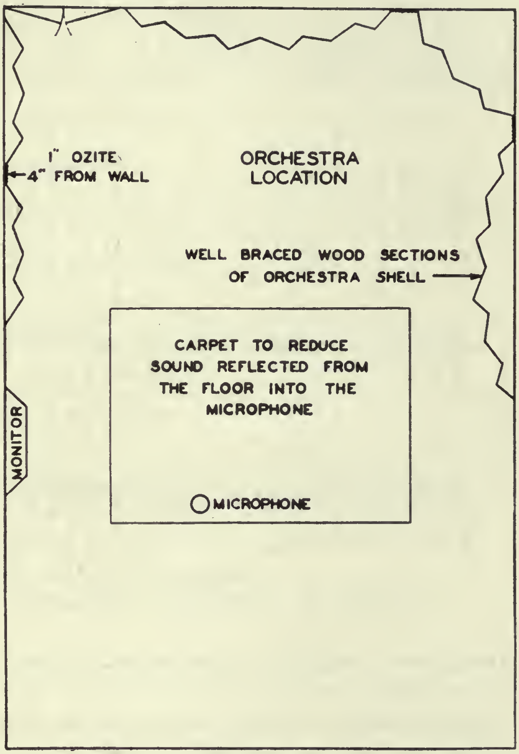

FIG. 2. Scoring stage plan.

(*1*) Parallel hard surfaces were eliminated in order to prevent the reflection of sound back and forth between them.

(*2*) Large, flat, hard surfaces were not used because of the danger of prominent first reflections from such surfaces into the microphone.

(*3*) Hard surfaces were not placed at right angles to each other, because sound might be reflected from such a combination back to the source.

(4) Convex, rather than concave, curvatures were used in order to avoid sound concentrations. Soft absorbing material was placed between adjacent convex sections of the orchestra shell.

(5) The hard orchestra shell surfaces were broken up in an irregular manner in order to avoid undesirable acoustic diffraction patterns.

The reverberation time-frequency characteristic, shown in Fig. 3, is smooth, as is desirable. The time at 512 cps. lies within the optimum band of Fig. 1. The sustained reverberation time at the high frequencies makes it possible to attain the brilliance required in musical recordings. The increase in reverberation time at the low

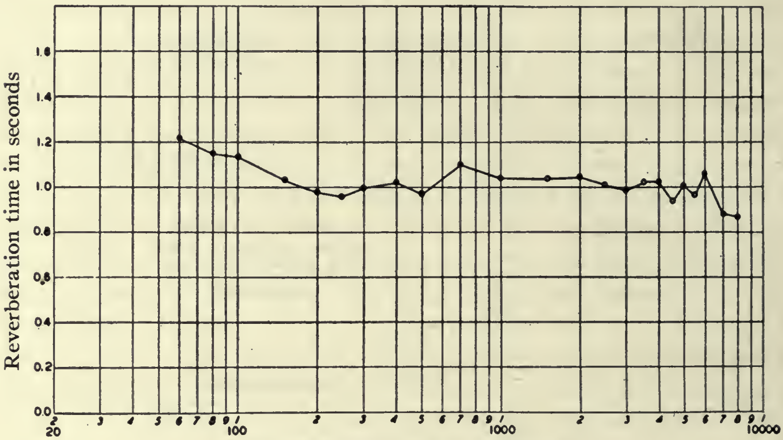

FIG. 3. Scoring stage reverberation characteristic.

frequencies is slight enough to guard against undesirable boominess in recordings.

It has been found desirable, in order to eliminate prominent first reflections from the wood floor into the microphone, to place carpets or other absorbing materials between the sound-source, such as the orchestra, and the microphone. It is obvious that the floor can not be broken up, as are the wall and ceiling surfaces, for the purpose of reducing the prominence of floor reflections. As an illustration of what may happen if such reflections are not avoided, measurements were made on a studio stage having a bare floor. The high-speed, automatic, level recorder charts of Fig. 4 represent measurements of a high-quality reproducing system. The instrument has been previously described by Wente, Bedell, and Swartzel.[4] When sound

reaches a microphone by two paths of different lengths, the component sounds alternately reinforce and interfere with each other as the pitch of the tone changes. Interference occurs when the wavelength of the sound from the loud speakers is twice the difference between the lengths of the two paths from the speakers to the microphone. Interference occurs also for each odd harmonic of this fundamental tone. Reinforcement occurs for each even harmonic. In the case of the charts of Fig. 4, for instance, the difference between the direct path from the loud speakers to the microphone, and the reflected path from the loud speakers to the floor to the microphone, was slightly greater than 3 feet. This corresponds to a difference in frequency in-

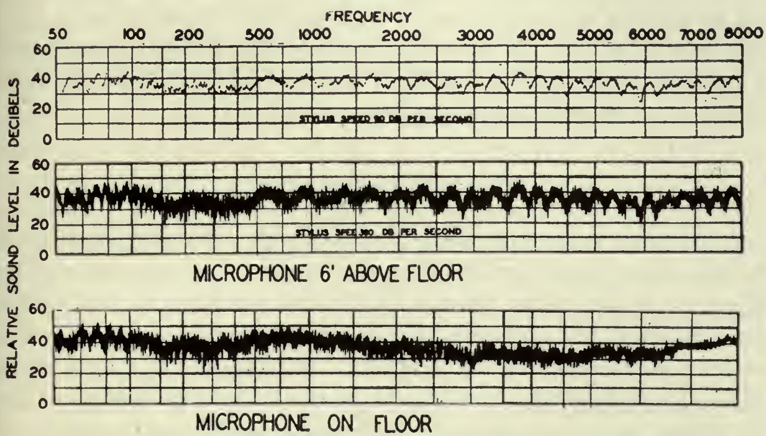

FIG. 4. Measurements showing effect of prominent floor reflection.

terval between reinforcements or interferences of 330 cps., which is in close agreement with the experimental fact as is evident by inspection of the first and second charts of Fig. 4. It can be seen from these charts that reinforcement occurred approximately at frequencies of 300, 600, 900, 1300, 1700, 2000, *etc.*, whereas interference occurred at frequencies of 400, 800, 1100, 1500, 1800, *etc.*, cps.

The first chart was made with the stylus of the high-speed automatic level recorder moving at the slowest speed of 90 db. per second. The second and third charts were made with the stylus moving at the rate of 360 db. per second. It is obvious from a comparison of the first and second charts that with the stylus moving at the higher speed, the acoustic pattern irregularities of the room become evident. The second chart, except for such irregularities, is the same as the

first. The third chart was made with the microphone resting upon a pad on the floor in order to decrease to a marked degree the difference in the lengths of the direct and reflected paths from the speakers to the microphone. With the microphone in this position, the difference in path lengths was a little less than 2 inches. The calculated difference in distance between the paths is in close agreement with the results shown by the chart, which indicate that interference occurred at a frequency of 4000 cps. and reinforcement at 8000.

It is evident from this discussion that care should be taken when designing scoring stages to reduce the prominence of first reflections by breaking up the wall and ceiling surfaces into small irregular areas, and by placing absorption upon the floor between the sound sources and the microphone. If this is done, greater freedom in the placement of the microphone for recording purposes can be permitted. If care is not taken, poor quality may result.

MICROPHONE PLACEMENT

In recording orchestral music it is desirable, wherever possible, to use one microphone rather than two or more connected through a mixer to the recording channel. The balance between the various instruments of the orchestra with single-microphone pick-up can be attained by rearranging the orchestra, bringing closer to the microphone the instruments that should be made more prominent. This applies also when a soloist and chorus are present as well as an orchestra. When the orchestra is used for accompaniment, the soloist is usually placed nearest the microphone, the chorus next, and the orchestra somewhat farther back. Acoustic perspective control can be achieved to some extent by adjusting the relative distances from the microphone of the soloist, chorus, and orchestra. The use of a single microphone probably represents the most natural arrangement, the microphone taking the place of the listener. Stereophonic or auditory perspective recordings are not considered in making this statement. Objections, however, have been made to this method of recording because of its lack of flexibility and ease of control. When sufficient time is not permitted for rehearsals and adjustments, auxiliary control methods have been used, which involve the use of more than one microphone. Because of the difficulties experienced in obtaining best quality under these conditions, preliminary experiments have been made to determine the rules under which more than one microphone

can be used without noticeably degrading the quality. The results attained are described in the following paragraphs.

When simultaneously using two or more microphones, undesirable results similar to those produced by prominent first reflections, described above and illustrated in Fig. 4, may occur unless precautions are taken. The automatic level recorder charts of Figs. 5, 6, and 7 show such effects. Two microphones were placed at different distances from a high-quality horn system in the West Coast review room of Electrical Research Products, Inc. Their combined output was connected through a mixer to the input of the high-speed automatic level recorder. A warble tone oscillator continuously variable from 50 to 8000 cps. was used as the sound-source. In making each measurement, the sound volumes picked up by the two microphones were adjusted to be equal. Figs. 5 and 6 contain parts of charts, each pair representing measurements made, first, with the two microphones electrically in phase and, second, with the microphones out of phase. The first two charts were made with the microphones each 5 feet from the loud speakers. It is evident that with the microphones out of phase, the measured sound level was much lower than with the microphones reinforcing each other. A more exact adjustment of the microphone positions would have resulted in more complete cancellation, and therefore a lower level over the frequency range than shown by the second chart of Fig. 5.

The second and succeeding pairs of charts were made with the distances between the microphones increased from 3 inches to 20 feet. It will be noted that as the distance was increased, the frequency differences between adjacent reinforcements or interferences was decreased. For example, with the microphones 3 inches apart, interferences occurred at frequencies of 2000 and 6000 cps., and reinforcements at 4000 and 8000 cps. The frequency interval in each case was 4000 cps. Connecting the microphones out of phase caused the interferences to occur where reinforcements occurred with the microphones connected in phase.

Listening tests were made of the quality of sound picked up by the two microphones under these test conditions. It was found that when the microphones were the same distance from the loud speakers and in phase, the quality was pleasing. This might be expected from the relatively smooth characteristic curve shown by the first chart of Fig. 5. When the microphones were electrically out of phase, the sound volume was reduced and the quality impaired. With small

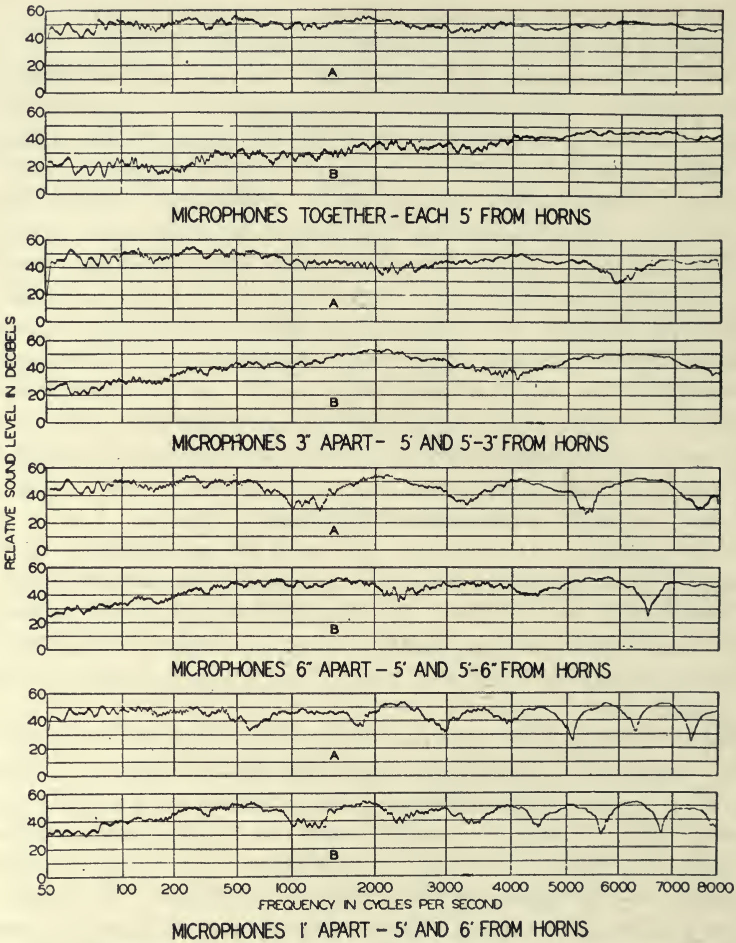

FIG. 5. Multiple-microphone pick-up measurements; microphones connected electrically in phase (*A*), out of phase (*B*).

microphone separations of 3 inches, for instance, the quality was not good, as might also be expected from an inspection of the third and fourth charts of Fig. 5. The quality was poorest, in the opinion of the listeners, when the microphone separation was 2 feet. At a distance of 10 feet, the difference between single-microphone and two-microphone pick-up was only slight. At a separation of 20 feet, it was difficult to notice a difference in quality.

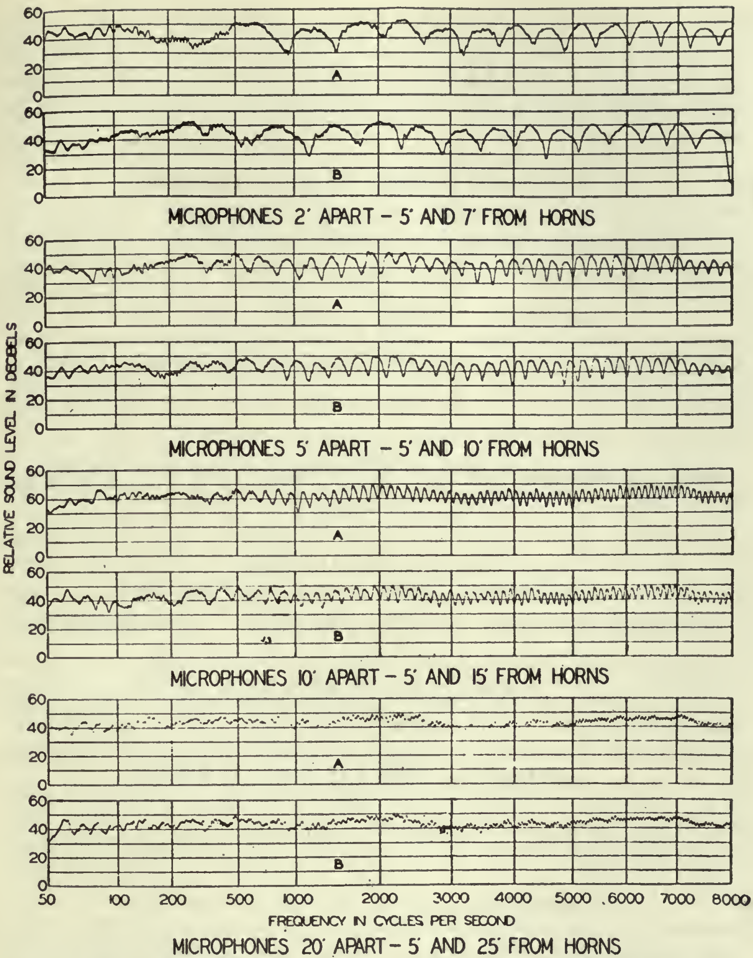

FIG. 6. Multiple-microphone pick-up measurements; microphones connected electrically in phase (A), out of phase (B).

Fig. 7 represents two supplementary series of tests with the microphones electrically in phase, the separation between microphones being 2 feet in every case. The first, second, and third charts were made with the more distant microphone at distances of 7, 15, and 25 feet, respectively, from the loud speakers. The third chart is a duplication of the fourth, except that the stylus of the high-speed level recorder was adjusted for maximum speed in the latter case. It is

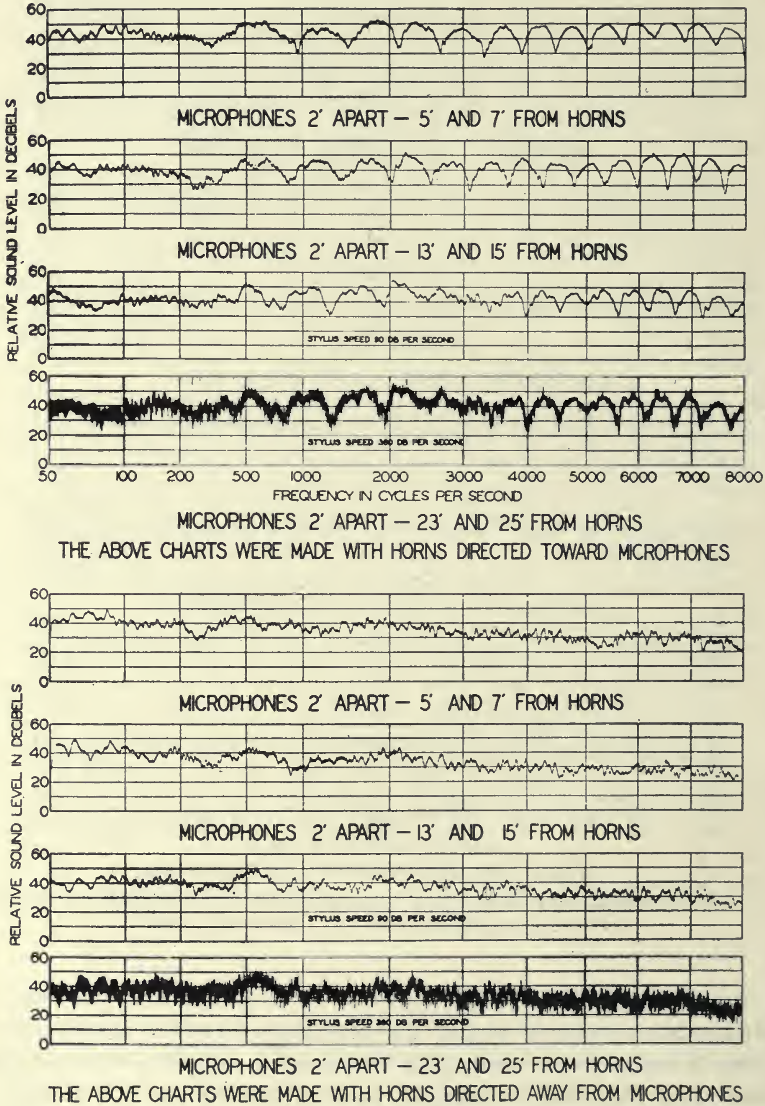

Fig. 7. Measurements showing effect of multiple-microphone pick-up.

evident from a comparison of the first three charts that the acoustic pattern of the room becomes only slightly more prominent as the microphones are moved farther from the speakers. This effect would have been more pronounced had not the loud speakers been directed toward the microphones.

In order to accentuate this room effect, the loud speakers in the next series of tests, represented by the four charts at the bottom of Fig. 7, were rotated 90 degrees, the loud speakers being directed toward one side of the room instead of toward the microphones. It is evident from the fifth, sixth, and seventh charts that the room-effect overshadowed the interference and reinforcement that occurred when the microphones were in the beam of the loud speakers. The reverberant energy under these conditions predominated, minimizing the difference in quality between single-microphone and multiple-microphone pick-up.

The effect of decreasing the direct energy from the horns as compared with the reverberant energy, can be seen by comparing the fourth chart with the eighth. The level of the sound energy, particularly at the high frequencies, was reduced by directing the output of the speakers away from the microphones. The irregularities throughout the frequency range also varied more widely in amplitude under the test conditions of the eighth chart of Fig. 7.

As a result of these preliminary measurements, which should be supplemented by further tests under representative recording conditions, the following conclusions have been drawn:

(*1*) When two or more microphones are used simultaneously with one recording channel, the difference in distance between them and the sound-source should be 10 feet or greater.

(*2*) The sound volume picked up by these microphones should be adjusted to differ as widely as is practicable, in order to reduce amplitude variations between sound reinforcements and interferences.

(*3*) The closer the microphones are to the sound-source, the more important it is to observe these rules, because the importance of the direct sound as compared with the reverberant sound increases as the microphones are moved closer to the sound-source.

(*4*) The more directional the sound-source, the more important it is to observe these rules. In the case of directional musical instruments, the objectionable features of multiple-microphone pick-up can be minimized by directing the instruments away from the microphones.

The author wishes gratefully to acknowledge the assistance given, particularly by J. P. Maxfield and E. W. Templin, in collecting the data and preparing this paper.

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DISCUSSION

Mr. Wolf: Those who have had experience in the theaters will recall the days when surfaces were treated with metal. We thought then it would be impossible to reproduce sound satisfactorily in those theaters, but it has since been found that such treatment afforded much low-frequency absorption and provided considerable high-frequency brilliance because of the reflections. As a result, those theaters were quite satisfactory. The tendency has been, of course, to go to lower periods of reverberation at the low frequencies and higher periods at the high frequencies.

There has been recently put upon the market a tile having a diaphragm action. If the tile is placed about 1 to 3 inches from the wall, and the sound-wave sets it in motion, the sound will be damped by the trapped air. It does not matter whether the tile is made of metal or of wood. We have known for a long time that if drapes are hung away from the wall they provide considerable low-frequency absorption. The tile can be damped by simple air damping, or by coating its surface with some kind of material.

Mr. Kellogg: Is it not possible to control the high-frequency and low-frequency absorptions rather nicely by placing an absorbent material behind a hard material having suitably spaced perforations? I can imagine, for example, that a hole-spacing can be selected that would afford a reduced absorption above 5000 cps., by spacing the holes a certain fraction of a wavelength apart. Then, if desired, additional absorption at low frequencies might be attained by large holes much farther apart, opening into larger cavities. Has that method been worked out?

Mr. Loye: I think the absorption can be more readily controlled by the thickness and character of the materials. The spacing of the holes does have a bearing upon the absorption characteristic, but I do not believe it is a controlling factor unless carried to extremes.

Mr. Kellogg: I did not fully understand in Fig. 2 whether all the surfaces indicated by the zigzag lines were covered with felt, or whether there was a little felt only here and there.

Mr. Loye: The jagged sections forming part of the orchestra shell of Fig. 2 are made of vertical wood sections, well braced, 20 feet high. Between these sections is absorbent material, which is placed several inches away from the

hard wall surface of the stage in order to provide the desired low- as well as high-frequency absorption.

MR. KELLOGG: Only a few relatively narrow strips of absorbent?

MR. LOYE: Yes. All the rest of the material of the orchestra shell is hard.

MR. TASKER: What is the treatment on the lower walls?

MR. LOYE: Masonite. This is an actual scoring stage, redesigned from an old sound stage to make it suitable for recording music. The reason for breaking it up in this manner was to diffuse the sound thoroughly, and allow a wide variation in positioning the microphone.

MR. BAKER: How much selective absorption would result by increasing the air-space between the corrugated sections and the wall?

MR. LOYE: Very little, because the tops of the sections in each case were boarded over in order to avoid resonance conditions such as organ pipe effects.

MR. BAKER: And if the corrugated sections were made of impervious but very thin material so that they could respond to the sound vibrations readily—?

MR. LOYE: Then there would be absorption of a particular kind. We made the stipulation that the sections must be well braced and thick enough so as not to vibrate in such a manner. We wanted to avoid such possibilities, which might have resulted in undesirable resonances.

MR. KELLOGG: Did you find that placing the microphone against the floor was a desirable arrangement?

MR. LOYE: No, indeed. It was put there only because that was an easy way to reduce the difference in distance between the direct and reflected sound paths to two inches or less. One can see by the nature of the curve that it would not be desirable.

MR. KELLOGG: The sound-source was some sort of music or speech coming from a loud speaker unit?

MR. LOYE: Yes.

MR. BAKER: Was the Masonite used on the ends of the wall soft Masonite?

MR. LOYE: Yes; and portions of the Masonite were combined with rock-wool in order to increase the absorption in that end of the stage.

MR. BAKER: How were the microphones kept out of phase? Were they really out of phase?

MR. LOYE: Yes. Reversing the connections of one of the microphones will put them 180 degrees out of phase.

MR. KELLOGG: You mean if you had brought them together in position they would have been out of phase? Considering the fact they were not adjacent to each other there would, of course, be a phase difference in their outputs.

MR. LOYE: That is right. Considered acoustically, they were not 180 degrees out of phase, except in the one case when the microphones were physically placed together.

MR. KELLOGG: Did you put anything behind the wood panels to cause some absorption in the trapped air?

MR. LOYE: Yes; either rock-wool, which was the material on the stage before the modifications were made, or soft Masonite. I have forgotten exactly which.

MR. KELLOGG: Not a masonry wall as shown in the straight-line outline?

MR. LOYE: No. It is constructed largely of soft Masonite or rock-wool.

A UNIDIRECTIONAL MICROPHONE*

H. F. OLSON**

Summary.—*Directivity has been found to be desirable in sound-collecting systems to improve the ratio of direct to generally reflected sounds and otherwise to discriminate against undesirable sounds. The bidirectional ribbon microphone is a pressure-gradient instrument, in which the response corresponds to the velocity component in a sound-wave. The pressure ribbon microphone is resistance controlled, and the response is a measure of the pressure component in a sound-wave. Combination of the outputs of the pressure and velocity ribbon microphones produces a unidirectional characteristic. This microphone has been found to be useful in sound motion picture recording, radio broadcasting, and sound reinforcing systems in which the desired sounds originate in front and the undesired sounds to the rear of the microphone.*

INTRODUCTION

Directivity has been found to be desirable in sound-collecting systems to improve the ratio of direct to generally reflected sound and otherwise to discriminate against undesirable sounds.[1,2] One of the important factors in a directive sound-collecting system is the solid-angle over which sound is received without appreciable attenuation. This must be sufficiently large to include the area occupied by the sources of sound to be received, but at the same time the angle must be small enough so that an appreciable gain against undesirable sounds is obtained. Another requirement is a directional characteristic that is independent of the frequency. A system that does not possess this characteristic will introduce frequency discrimination. In general, the particular directional characteristics will depend upon the pick-up problem. For example, the bidirectional ribbon microphone has been found to be very useful for overcoming excessive reverberation and other undesirable sounds and as a tool for attaining a "correct balance" of the received sound.

The bidirectional ribbon ("velocity" or "pressure gradient") microphone[1,3,4] consists of a light, corrugated ribbon suspended in a magnetic field. The ribbon is driven from its position of equilibrium

* Presented at the Spring, 1936, Meeting at Chicago, Ill.

** RCA Manufacturing Co., Camden, N. J.

by the difference in pressure between the two sides. The vibration of the ribbon leads to the induction of an emf. corresponding to the undulations of the incident sound-wave. The directional characteristics of this microphone are shown in Fig. 1.

For certain types of recording it was apparent that a microphone that had a unidirectional characteristic would be very useful. This is particularly desirable in sound motion picture work in which the camera may be placed in a region in which the microphone sensitivity is low and noise from the camera thereby diminished, while the actors move about in the high-sensitivity region. Also, in

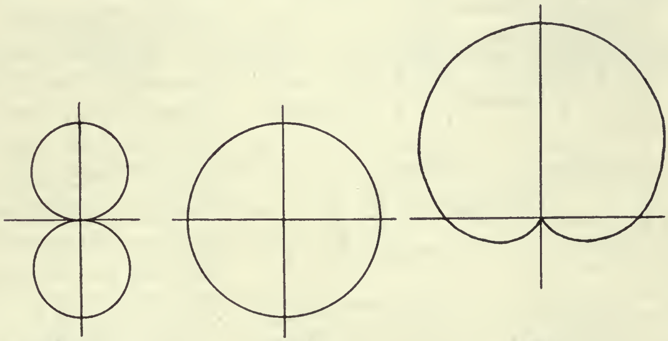


Fig. 1. Fig. 2. Fig. 3.

FIG. 1. Directional characteristic of pressure-gradient microphone: $E = E_0 \cos \theta$.

FIG. 2. Directional characteristic of pressure microphone: $E = E_0$.

FIG. 3. Directional characteristic of combination: $E = E_0 (1 + \cos \theta)$.

theater sound-reinforcing systems for stage collection the logical position of the microphone is in the footlight trough, in which case it is desirable to receive sounds emanating from the stage and eliminate sounds coming from the audience or orchestra.

The bidirectional ribbon microphone comprises a system in which the velocity of the ribbon is in phase with the particle velocity in the sound-wave. Referring to Fig. 1, the phase of the output of a velocity microphone in the two pick-up zones differs by 180 degrees. Now, if this is combined with a microphone in which both the sensitivity and the phase are independent of the direction (Fig. 2), the resulting characteristic will be a cardioid of revolution, as shown in Fig. 3, provided that the sensitivity of the non-directional unit is equal to the maximal sensitivity of the bidirectional unit.

It is evident that a pressure-operated microphone is required that can be incorporated with the bidirectional ribbon microphone and at the same time retain uniform response and directional characteristics. Furthermore, the phase relation between the voltage output of the pressure microphone and the pressure in the sound field must be suitable for combining with the bidirectional ribbon microphone in order to produce a cardioid characteristic. In the microphone as finally developed,[5,6] Fig. 4, a single ribbon is used, one part of which is velocity operated and the other part pressure operated. The voltages induced in the two portions are in phase for sounds originating in front of the microphone and are 180 degrees out of phase for the opposite direction. The directional characteristic up to a fairly high frequency is of the desired cardioid shape. It is the purpose of this paper to describe the theory and operation of the combination of a pressure and a velocity-actuated ribbon microphone to form a microphone having a unidirectional characteristic.

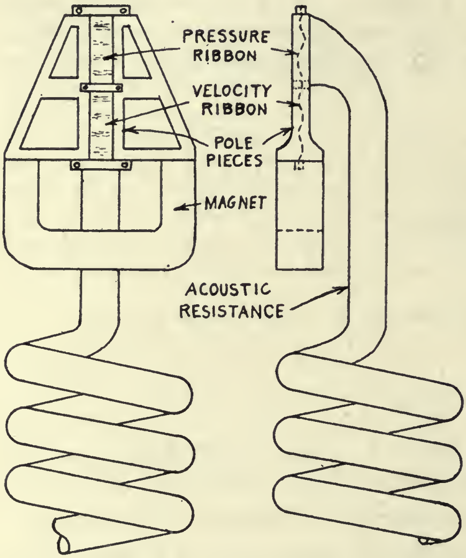


FIG. 4. Diagram showing essential elements of unidirectional ribbon microphone.

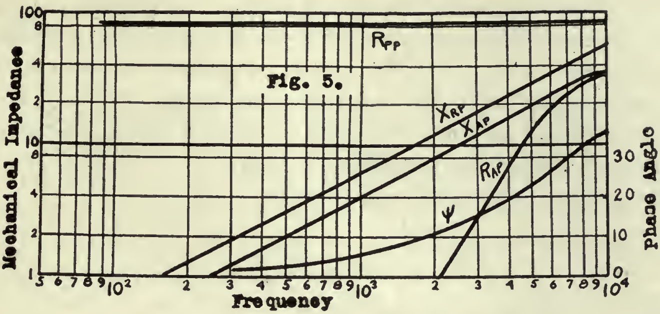
PRESSURE-ACTUATED RIBBON MICROPHONE

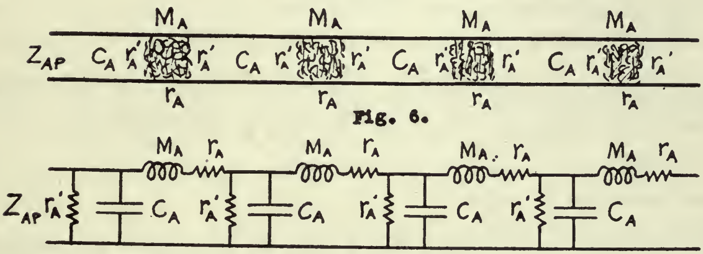
The pressure ribbon microphone consists of a light metallic ribbon suspended in a magnetic field and freely accessible to the atmosphere on one side and terminated in a suitable acoustic impedance on the other side (Fig. 4).

The voltage generated by the ribbon is given by the equation

$$e = Bl\dot{x} \tag{1}$$

where B = flux density
l = length of the ribbon
$\dot{x}$ = velocity of the ribbon





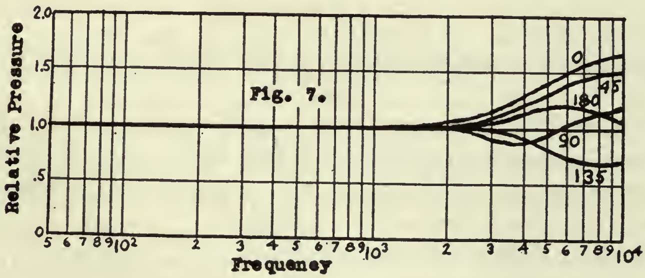


FIG. 5. (*Upper*) Pressure microphone impedance characteristics of components of mechanical system:

X_{RP}, mechanical reactance of ribbon
X_{AP}, mechanical reactance due to air
R_{AP}, mechanical resistance due to air
R_{PP}, mechanical resistance terminating ribbon
ψ, phase-angle between pressure of plane sound-wave and ribbon velocity.

FIG. 6. (*Center*) Equivalent electrical circuit of pipe damped with tufts of felt.

FIG. 7. (*Lower*) Theoretical directional characteristics of pressure ribbon microphone; assumed to be same as sphere 0.8 inch in diameter.

The ribbon, in a microphone of uniform sensitivity, should have at all frequencies the same velocity per unit pressure in the actuating sound-wave. Another factor is that of phase: in order to combine this microphone with the velocity microphone, the velocity of the system must be in phase with the pressure in the sound-wave at all frequencies within the transmission band.

The velocity of the ribbon is given by

$$\dot{x} = \frac{pA_R}{R_{PP} + R_{AP} + jX_{RP} + jX_{AP}} \tag{2}$$

where p = pressure in the sound-wave
A_R = area of the ribbon
The other quantities are as described in the text that follows.

The mechanical reactance X_{RP} due to the mass of the ribbon is shown by the graph of Fig. 5, and is given by the expression

$$X_{RP} = j\omega m \tag{3}$$

where m = mass of the ribon.

The mechanical impedance due to the air load upon the ribbon is

$$Z_{AP} = R_{AP} + jX_{AP}$$

The resistive R_{AP} and the reactive X_{AP} components are shown in Fig. 5.

The mechanical impedance due to the electrical circuit and the mechanical impedance due to the aperture between the ribbon and the pole-pieces are, in general, negligible compared to the other impedances in the system, and may be neglected.

An examination of the characteristics X_{RP}, X_{AP}, and R_{AP} shows that all increase with frequency. Since, for constant sound pressure, the force available for driving the system is independent of the frequency, the impedance that controls the system should be independent of the frequency in order that the velocity of the ribbon should be independent of the frequency. This means that the mechanical resistance R_{PP} terminating the back of the ribbon should be larger than the other impedances. Furthermore, the phase-angle between the velocity of the ribbon and the actuating force should be small. This means that the resistive components should be large compared to the reactive components.

The ideal form of such an acoustic resistance is a long pipe. The acoustic resistance of an infinite pipe is

$$r_{PP} = \frac{42}{A_P} \tag{4}$$

where A_P = area of the pipe.

An extremely long pipe is too cumbersome for practical purposes. However, it is possible to design a shorter iterative system that will be resistive above a certain low frequency. Consider as a specific example a pipe 2 meters long, closed at one end, and having a cross-section of 1.9 sq. cm., but not loaded with any absorbing material. The dissipation in this sort of pipe is small, and the reflection at the end will result in standing-wave systems. The particular problem here is to introduce sufficient damping so that reflection from the end will not occur, and at the same time retain a system that will exhibit a pure resistance of constant value over the desired frequency range. It has been found that tufts of felt result in very satisfactory damping. Fig. 6 shows the method and the equivalent electrical circuit. If the quantity of felt is large and packed tightly, M_A and r_A will be large, in which case Z_{AP} will be larger than $42/A_P$. If the felt is loosely packed, M_A and r_A will be small, and r'_A will be large; in this case there will be small attenuation in the system and the wave reflected from the end will be large, resulting in a non-uniform impedance-frequency characteristic. By proper choice of the constants, we can obtain a system that will practically satisfy the conditions of an acoustic resistance of the value $r_{AP} = 42/A_P$ at the point Z_A. Of course, obviously at very low frequencies the system becomes capacitive. This is determined by the volume of the pipe. The impedance of the pipe was measured on an acoustic impedance bridge and the correct proportions of felt determined.

The mechanical resistance of the pipe referred to the ribbon is given by

$$R_{PP} = \left(\frac{42}{A_P}\right) A_R^2 \tag{5}$$

where A_P = area of the pipe
A_R = area of the ribbon

A true pressure-measuring instrument should not discriminate as to direction. To attain this objective in any pressure-measuring instrument, the dimensions must be small compared to the wave-length of the sound-wave. In the pressure type of ribbon microphone, where an acoustic resistance line is used in back of the ribbon,

it is difficult to attain absolutely uniform response for all directions at the extremely high frequencies because of sound diffraction effects around the feed-pipe to the acoustic line (Fig. 4). The feed-pipe, together with the pole-pieces, form a volume around which the sound is diffracted. In cases like this it has been found that the diffraction around a sphere of equal volume may be computed, and a reasonably good estimate of the performance obtained.

The volume of the structure involved in this microphone is equiva-

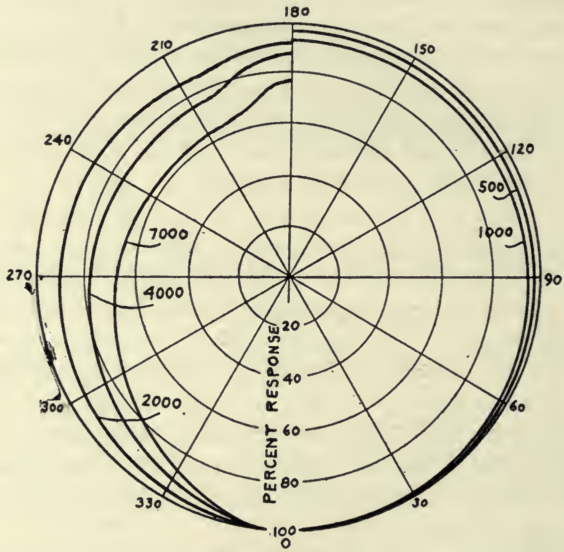
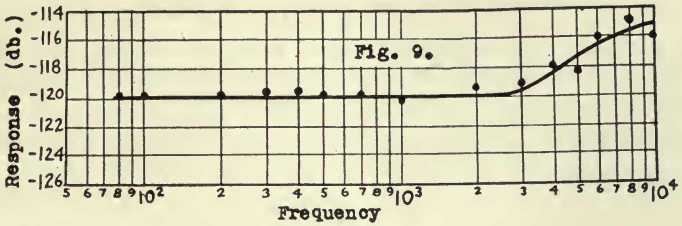
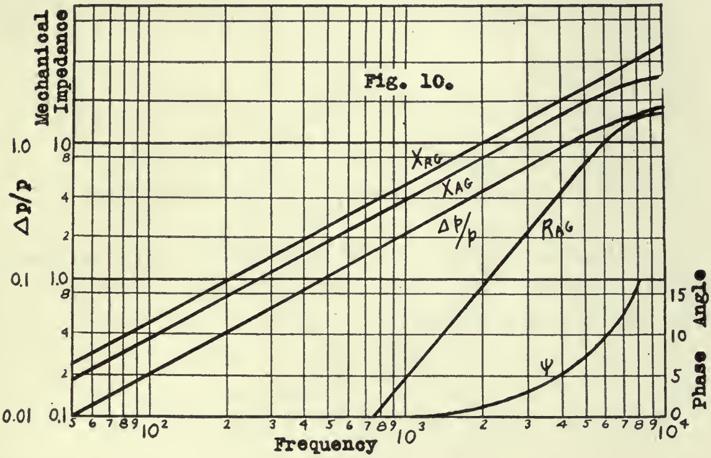


FIG. 8. Directional characteristics of pressure-actuated portion of unidirectional microphone at various frequencies.

lent to a sphere 0.8 inch in diameter. The theoretical characteristics for such a sphere are shown in Fig. 7. The observed directional characteristics of the pressure component of the unidirectional microphone are shown in Fig. 8.

The generated electromotive force developed by the motion of the ribbon computed from equations *1* and *2* and the pressure and impedance values shown in Figs. 5 and 7 is shown in Fig. 9. The experimentally determined response is also shown in Fig. 9.





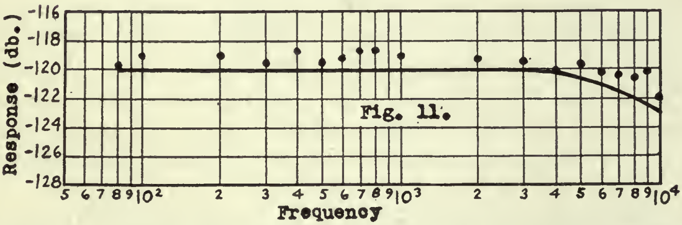


FIG. 9. (*Upper*) Theoretically predicted and experimental response of pressure-operated ribbon microphone at 0 degree (zero db. = 1 volt). Note: Data show open-circuit voltage of ribbon.

FIG. 10. (*Center*) Velocity microphone; impedance characteristics of components of mechanical system:

X_{RG}, mechanical reactance of ribbon
X_{AG}, mechanical reactance due to air
R_{AG}, mechanical resistance due to air
$\Delta p/p$, ratio of pressure difference between the two sides to the pressure of the sound-wave
ψ, phase-angle between velocity of ribbon and pressure in plane sound-wave.

FIG. 11. (*Lower*) Theoretically predicted and experimental response of pressure-gradient (velocity) ribbon microphone at 0 degree (zero db. = 1 volt). Note: Data show open-circuit voltage of ribbon.

VELOCITY-ACTUATED RIBBON MICROPHONE

In the velocity ribbon microphone, as previously stated, the ribbon is driven from its equilibrium position by the difference in pressure between the two sides. This difference in pressure is due to the difference in phase between the two sides, and for a plane wave is given by the expression,

$$\Delta p = 2Kc\rho\, A \cos (Kct) \sin Kd \tag{6}$$

where $K = 2\pi/\lambda$
λ = wavelength
ρ = density of air
c = velocity
A = amplitude of ϕ
ϕ = velocity potential
d = effective acoustic path between the two sides of the ribbon

The instantaneous pressure available for driving the acoustical and mechanical systems of the microphone is shown in Fig. 10. The velocity of the ribbon is given by

$$\dot{x} = \frac{\Delta p\, A_R}{jX_{RG} + R_{AG} + jX_{AG}} \tag{7}$$

The mechanical reactance X_{RG} due to the mass of the ribbon is shown in Fig. 10, and is given by the expression. The resistive R_{AP} and reactive X_{AP} components due to the air load upon the ribbon are shown in Fig. 10. The generated electromotive force developed by the motion of the ribbon computed from equations *1* and *7* is shown in Fig. 11. The experimentally determined response is also shown in Fig. 11.

The foregoing considerations have been concerned with the face of the ribbon normal to the line of propagation of the sound. When the normal to the face of the microphone is inclined by the angle θ to the line of propagation, the air distance from front to back is multiplied by the factor $\cos \theta$.

The observed directional characteristics of the velocity portion of the unidirectional microphone are shown in Fig. 12. It will be seen that the experimental results are in close agreement with the predicted performance. The results indicate that the directional characteristics of the microphone are practically independent of the frequency.

UNIDIRECTIONAL MICROPHONE (COMBINATION OF PRESSURE AND VELOCITY MICROPHONES)

In the preceding sections two types of microphone have been discussed: namely, a microphone the response of which is a measure of the pressure in a sound-wave, and a microphone the response of which is a measure of the particle velocity in a sound-wave.

The electromotive force generated by the motion of the ribbon due to an incident sound-wave in the case of the velocity ribbon microphone is shown in Fig. 11. Fig. 10 shows that the velocity of the

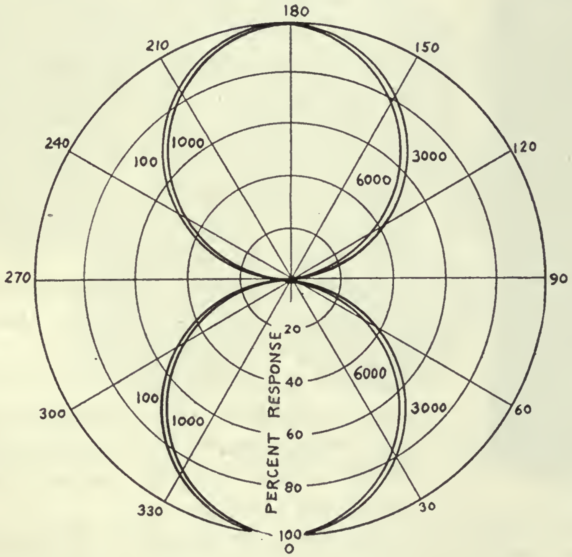


FIG. 12. Directional characteristics of velocity-actuated portion of unidirectional microphone at various frequencies.

ribbon, and hence the generated electromotive force, is practically in phase with the velocity in a plane sound-wave.

The electromotive force generated by the motion of the ribbon due to an incident sound-wave in the case of the pressure ribbon microphone is shown in Fig. 9. Fig. 5 shows that the velocity of the ribbon, and hence the generated electromotive force, is practically in phase with the pressure in a plane sound-wave.

Assume that the voltage output e_v of the velocity microphone for $\theta = 0$ is made equal to the voltage output e_p of the pressure micro-

phone. Now connect the two ribbons in series, and the combined output will be

$$e_{ud} = e_p + e_v \cos \theta \tag{8}$$

The directional characteristic will be as shown in Fig. 3, and is a cardioid of revolution with the axis of revolution normal to the plane of the ribbon. This combination of pressure and velocity ribbon microphone has been termed a unidirectional microphone.

FIG. 13. The unidirectional microphone.

A model of this microphone is shown in Figs. 13 and 14. A single ribbon is used, divided into two parts, one part of which is velocity-operated and the other pressure-operated. The velocity portion is left open, and the back of the pressure portion is terminated in a pipe connected to a labyrinth (which is equivalent to a pipe) housed in a cylinder as shown in Fig. 14.

The observed directional characteristics of the unidirectional microphone in the horizontal plane are shown in Fig. 15. It will be seen that the observed directional characteristics are cardioids of revolution up to fairly high frequencies. This substantiates the theory of the velocity, pressure, and unidirectional microphones.

The response frequency characteristic of the microphone is shown in Fig. 16. It will be seen that the response is uniform over a wide frequency range. The observed response is in very good agreement with the theoretically predicted response.

The efficiency of energy response of the unidirectional microphone as compared to a non-directional microphone for sounds originating from random directions, all directions being equally probable, is

$$\text{Efficiency} = \frac{\sum_{\varphi=0}^{\varphi=4\pi} e^2_{ud\phi}}{\sum_{\varphi=0}^{\varphi=4\pi} e^2_{ud\phi}}$$

$$= \frac{2\pi e_0^2 \int_0^\pi (1 + \cos\theta)^2 \sin\theta \, d\theta}{16\pi \, e_0^2} = \tfrac{1}{3} \tag{9}$$

The following conclusion can be drawn: The energy response of the unidirectional microphone to sound originating from random directions is one-third that of a non-directional microphone. For the same

FIG. 14. Unassembled view of unidirectional microphone, showing pressure and velocity portions of the ribbon, magnetic structure, labyrinth, and pipe connecting pressure part of ribbon to labyrinth.

allowable reverberation, the unidirectional microphone can be used at 1.7 the distance of a non-directional microphone.

APPLICATION OF THE UNIDIRECTIONAL MICROPHONE

The large angle over which this microphone receives sound without appreciable attenuation indicates that a very wide range of action can be covered with a single microphone. For example, the response at 60 degrees is only 2.5 db. below that at 0 degree. On the other hand, the response is relatively small for angles larger than 90 degrees. For example, the response at 120 degrees is 12 db. below that at 0 degrees, 17 db. below that at 135 degrees, *etc.* It has been found that this type of directional characteristic is particularly useful for creating an illusion of reality, for discriminating against undesirable sounds, for attaining the correct balance of intensities of a group

of sounds, and for controlling the reverberation characteristic of the received sounds.

To enhance the artistic effect of the collected sound it is important that the apparent distance of the sound, as estimated by the ear in the reproduction, be compatible with the apparent distance of the projected picture, as seen upon the screen. In the case of an orchestra, it has been found that the collection distance must be relatively large. Equation *9* shows that, with all the other factors the same, this distance can be made larger in the case of the uni-

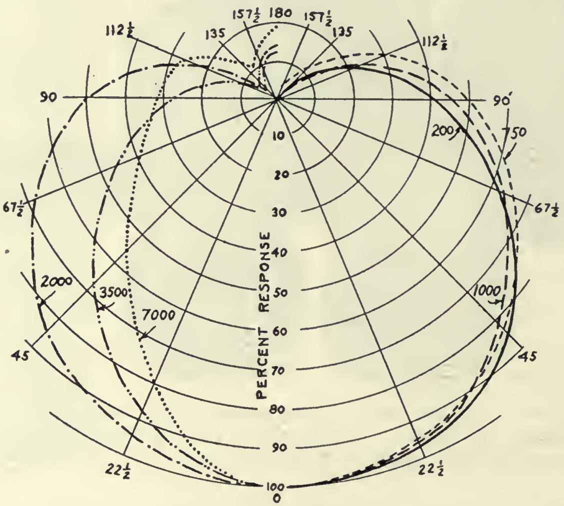


FIG. 15. Directional characteristics of unidirectional microphone at various frequencies.

directional microphone. If the non-directional microphone is used over the same large distance it is found that the reverberation is, in general, very great, and that the reproduced sounds lack definition. On the other hand, if the reverberation is reduced by the use of more absorption, the brilliance of the recorded sound is reduced because of the short period of decay. The use of the unidirectional microphone makes it possible to achieve (*a*) more realistic reproduction by reason of better definition of the individual instruments, due to the greater ratio of direct to reflected sound; and (*b*) more pleasing reproduction, by reason of the relatively long reverberation time.

When one listens normally with both ears he is able to focus his

attention upon the main source of action and subconsciously attenuate noises or incidental sounds that may be present. In sound reproduction it is important that similar emphasis be placed upon the main action and a corresponding discrimination be exercised against undesired sounds. Fig. 17 illustrates the use of the unidirectional microphone for this purpose. The action centers about the characters seated at table *2*. In the case of a non-directional system, the ratio of the direct sounds received from the characters at table *2* to that received from the other tables is a function only of the relative distances. To attain a satisfactory ratio, in general, means that the distance from the desired source to the microphone should be quite small. To achieve the correct artistic effect the pick-up distance must be comparable to the camera distance. As a consequence,

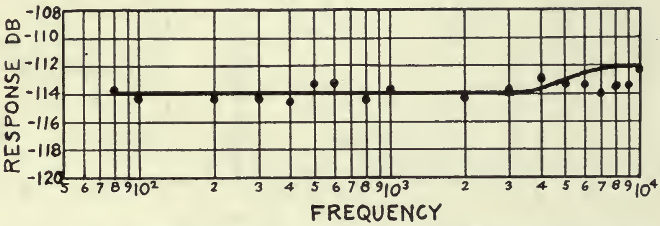


FIG. 16. Theoretically predicted and experimental response of unidirectional microphone at 0 degree (zero db. = 1 volt). Note: Data show open-circuit voltage of ribbon.

when this condition is satisfied the distances from the three tables in this example are not widely different. Therefore, by using a directional microphone, another parameter is available for attenuating the sounds from tables *1* and *3* with respect to table *2*. Furthermore, by properly orienting and locating the microphone the relative ratio of the intensities of the sounds from tables *1* and *3* can be adjusted to what one would actually hear were he located at the "distance" of the camera.

Fig. 17 illustrates also the use of the unidirectional microphone for reducing noise pick-up from the camera. The camera is located behind the microphone; that is, in the region in which the response is small.

A person listening normally with both ears localizes the azimuth of the sound primarily by means of binaural triangulation. In the foregoing example an illusion of azimuth is accomplished by adjusting

the relative intensities of the sounds in accordance with what one would normally hear in listening to the action first-hand. In listening normally the sound is further localized, as regards distance, by the time relations between the direct sound and the sound reflected from the boundaries, as shown in Fig. 17. If a unidirectional microphone is used, the pencils of sound reflected from the walls *A* and *C* will be attenuated more than those reflected from wall *B*. The relative time-intervals of the direct sound and the sound reflected from wall *B* aid in establishing the perspective of the sound. This illustrates how

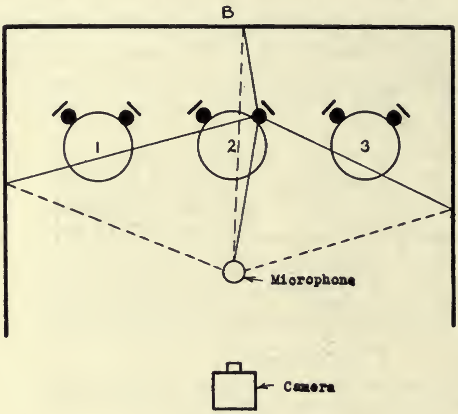


FIG. 17.

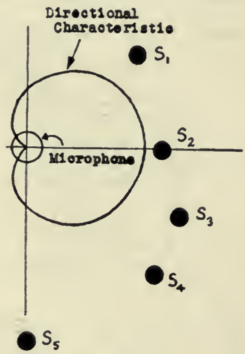


FIG. 18.

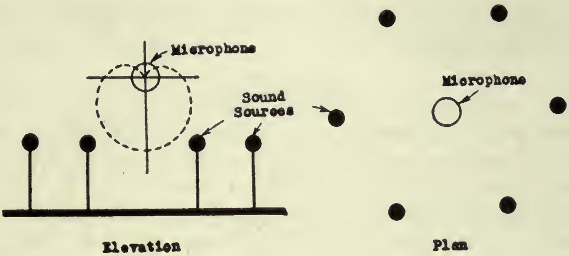
FIG. 17. Arrangement for emphasizing action and discriminating against undesired sounds, and for creating illusion of position of source by utilizing relative times and intensities of direct and reflected sounds.

FIG. 18. Arrangement for obtaining correct balance and reverberation of instruments of orchestra.

an illusion of depth or perspective of the recorded sound can be established by the time-interval and the relative intensities of the direct and reflected sounds reaching the microphone, and by excluding or attenuating sounds that would not normally contribute to the perspective.

The recording of an orchestra is a salient example of the value of a unidirectional microphone. In reproducing music there are two important factors: namely, (*1*) correct balance, or relative intensities of the various instruments, and (*2*) correct reverberation of the reproduced sound. In a non-directional system only one parameter, the distance, is available for controlling the intensity and effective

reverberation of the recorded sound. However, in the case of the unidirectional microphone two parameters are available. A plan view of a unidirectional microphone and a group of sound-sources is shown in Fig. 18. In this instance sound-source S_2 is to be emphasized, and is therefore placed upon the axis and quite close to the microphone. This results in high recorded intensity and low recorded



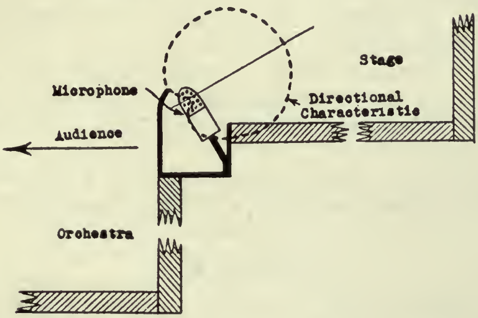


FIG. 19. (*Upper*) Arrangement for collecting sounds with equal efficiency over an angle of 360 degrees.
FIG. 20. (*Lower*) Illustrating the use of the unidirectional microphone for collecting sounds from the stage and excluding sounds from the orchestra and audience.

reverberation. Sound-source S_5 is placed at an angle of 90 degrees, in which case an attenuation of the direct sound of 6 db. results, due to the directional characteristic of the microphone. This illustrates that practically any value of loudness as well as of effective reverberation can be attained by suitably orienting and positioning the sound-sources with respect to the microphone.

In certain types of recording, it is desirable to place the microphone at the center of the action, directed downward, and collect sounds over an angle of 360 degrees with respect to the microphone.

One example of how this may be accomplished is illustrated in Fig. 19. Another modification of this arrangement is to place the microphone near the floor, pointing upward.

In public address and sound reënforcing systems the microphones are usually placed in the footlight trough or near the front of the stage (Fig. 20). Here the directional characteristics of the microphone are exceptionally suitable because of the desire to pick up sounds from the stage and to exclude sounds coming from the orchestra and the audience.

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DISCUSSION

MR. DEPUE: How does this microphone compare in open space, and in response to the wind, with the condenser type of microphone?

MR. OLSON: It is probably more affected by the wind than the condenser type. However, all microphones are affected by the wind, and it is usually necessary to use a wind shield.

MR. KELLOGG: Does the tube that acts as an acoustic impedance shield the back over just about half the ribbon height?

MR. OLSON: It is necessary that the pipe cover a little more than half, in order that the output of the pressure ribbon be the same as that of the velocity ribbon.

MR. KELLOGG: Are the pressure and the velocity portions 90 degrees apart in phase? Do the two parts of the ribbon act practically independently; or do they execute a combined motion due to the combined forces acting on the single diaphragm?

MR. OLSON: The two parts of the ribbon may act independently. For example, for a plane wave striking the microphone from the front, the two ribbons vibrate exactly in phase. For the same wave striking the microphone from behind, the two ribbons vibrate with a phase difference of 180 degrees. The

ribbon is physically anchored at the boundary between the velocity and the pressure sections.

MR. KELLOGG: Are the pressure and velocity in phase?

MR. OLSON: The pressure gradient or resultant driving force is 90 degrees ahead of the particle velocity. The mass reactance of the ribbon and associated system introduce a lag of 90 degrees. Therefore, the velocity of the ribbon is in phase with the particle velocity.

MR. KELLOGG: —the response of the mass being to velocity or pressure gradient?

MR. OLSON: In the case of the microphone, the response corresponds to either the pressure gradient or velocity.

MR. KELLOGG: It has been my understanding of the velocity microphone that the diaphragm was so light that it moved practically with the air.

MR. OLSON: The ribbon is relatively light, and therefore the magnitude of the ribbon velocity is practically the same as the particle velocity in the sound-wave.

MR. KELLOGG: If, by putting some kind of shield behind the velocity microphone, of highly absorbent material, will a reasonably satisfactory unidirectional microphone result? It would not be expected to have the same directional characteristic, because its purpose would be to block off completely one-half the response; but how good a unidirectional microphone could we make in that way?

MR. OLSON: If the shield is of dimensions greater than the wavelength, it is possible to shut out practically all sound coming from behind. However, a shield greater than the wavelength at low frequencies becomes so large that it is impracticable. If the shield is smaller than the wavelength, the blocking effect is very small. Therefore, a shield of reasonable dimensions would be directional for the higher frequencies and non-directional for the lower frequencies.

MR. WOLF: Does the selective characteristic cause any trouble from certain direct reflections? Would a direct reflection from a source stand out more than in a non-directional microphone because of the selective characteristic?

MR. OLSON: Troublesome direct reflections may be eliminated by properly orienting the microphone. By employing a directional microphone a direct reflection can be made either more outstanding or less outstanding than with a non-directional microphone, by changing the azimuth of the microphone with reference to the reflected sound.

MR. WOLF: If the reflections should be more or less discrete, rather than occurring as a general reverberation, they might stand out because of that.

MR. OLSON: That, of course, is possible under certain conditions, but the microphone can usually be oriented to reduce or eliminate such reflections.

MR. WOLF: Are the microphones available at the present time?

MR. FRANK: A few have been made for orders, but production lots will be available in a few weeks.

HARMONIC DISTORTION IN VARIABLE-DENSITY RECORDS*

BURTON F. MILLER**

Summary.—*Wave-form distortion in variable-density records caused by improper track processing and the ribbon velocity effect of the light-valve is considered from both theoretical and experimental standpoints. General agreement between calculated and experimental values of second-harmonic distortion is attained. Observed values of third-harmonic distortion are considerably greater than those predicted by the theory. Data obtained indicate that rather high values of distortion may result due to non-linearity of the relation between negative track exposure and print transmission.*

Recent advances in the design of theater sound equipment, embracing the development of practically flutter-free sound-heads, amplifiers of greater power capacity and lower harmonic distortion, and loud speaker systems of extended frequency range and higher acoustic output ratings have resulted in such an improvement in the fidelity of theater reproduction as to warrant increasing attention to the degree of distortion present in sound print releases.

Theoretical and experimental studies of the various elements and processes involved in typical motion picture sound recording have indicated that the recorder light-modulating device and departures from optimal photographic processing of sound-track are responsible for a major portion of the distortion normally present in release prints. The results of some of these studies pertaining to variable-density track as recorded by means of the Western Electric light-valve form the basis of this paper. The first portion of the paper will be restricted to the derivation of equations expressing the transmission of the print in terms of the time variations of the geometry of the light-valve aperture and the over-all gamma of the print. The second portion will be devoted to the presentation of experimental data on print distortion, and the correlation of calculated and observed values of distortion.

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* Presented at the Spring, 1936, Meeting at Chicago, Ill.

** Warner Bros. Pictures, Inc., Hollywood, Calif.

THEORY

The construction and principle of operation of the Western Electric light-valve are now so generally known as to make a detailed description of them superfluous. Suffice it to say that the light-valve effectively forms a slit whose length remains fixed, and whose width is controlled by the magnitude and direction of current flow through the ribbon loop that forms the slit. In normal recording practice the light-valve slit is illuminated by a light-source of constant intensity, and an optically reduced image of the slit is formed in the plane of the film in the recording machine. The unmodulated dimensions of the slit image are normally of the order of $^1/_8$ inch in length and 0.0005 inch in width, the length of the slit image being perpendicular to the direction of film motion.

Since the exposure of film is quantitatively measured by the product of the exposing light intensity and time of illumination of the film, it is apparent that as long as the film passes the slit image with constant linear velocity, the negative exposure of any point on the film is directly proportional to the time required for that point to traverse the width of the slit image. During the process of recording variable-density sound-track by means of the light-valve, the slit-image width varies in direct relation to the variations in waveform of the sound currents passing through the valve ribbons. The time of exposure of any point on the negative sound-track is therefore a function of two limits, the first corresponding to the instantaneous ribbon current amplitude at the instant at which the point enters the slit image, and the second corresponding to the instantaneous ribbon current amplitude at the instant at which the point leaves the slit image. If the slit image were of infinitesimal width, the time of exposure of any point on the sound-track would be infinitesimally short, and the exposure of every point on the track would be directly proportional to the wave-form of the sound currents passing through the light-valve ribbons. Actually, however, the slit image is of finite width, and at the higher recording frequencies the exposure of the track may depart considerably from the ideal value attained with a slit of infinitesimal width.

The wave-form finally obtained on a variable-density sound print is not only dependent upon the wave-form of negative exposure but also is a function of the over-all photographic gamma of the print. For the case in which the over-all print gamma is unity, and when recording is restricted to the straight-line portions of the negative

and positive H&D curves, the print distortion is theoretically equal to the wave-form distortion introduced by the light-valve. For cases in which the over-all print gamma departs from unity, the print distortion is a function of that introduced by the light-valve and the processing.

The wave-form distortion due to the light-valve may be determined quite simply by a method similar to that employed by Shea, Herriott, and Goehner,[1] which appeared earlier in this JOURNAL. Referring to Fig. 1, let MM' and NN' represent the normal unmodulated

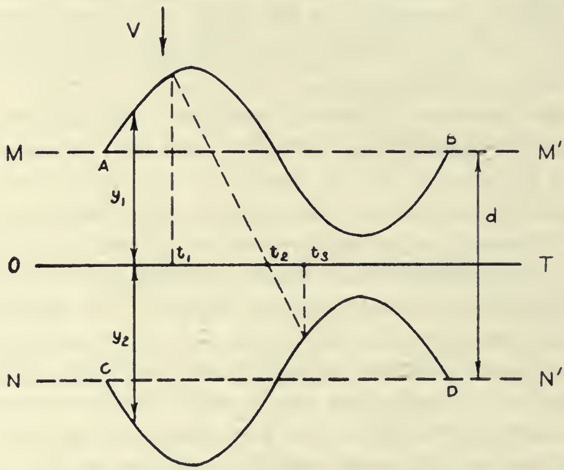

FIG. 1. Method of determining effect of ribbon velocity upon exposure.

positions of the upper and lower edges of the light-valve slit image, respectively. Also, let AB and CD indicate the successive instantaneous positions of the upper and lower edges of the slit image, respectively, during sinusoidal modulation of the valve. Let time be measured along the neutral axis of the image, OT, and denote the average unmodulated width of the slit image by d. Then, for sinusoidal modulation of the slit-image width, the instantaneous upper and lower image edge displacements from the neutral axis are given by:

$$y_1 = \frac{d}{2}\left(1 + m \sin \omega t\right) \tag{1}$$

$$y_2 = -\frac{d}{2}\left(1 + m \sin \omega t\right) \tag{2}$$

where $\omega = 2\pi$ times the applied modulating frequency
$m =$ modulation fraction.

For analytical reasons it is advantageous to regard the exposure as consisting of two portions; the first portion, T_1, will be regarded as that received while the point on the film under consideration passes from the upper edge of the slit image to the neutral axis. The second portion of the exposure, T_2, will be regarded as that received while the point on the film passes from the neutral axis to the lower edge of the slit image.

Let the position of any point x on the film referred to the neutral axis OT be given by:

$$y_3 = b - vt$$

where b is a constant, and
v is the velocity of the film in inches per second.

The exposure T_1 starts when $y_3 = y_1$, or when

$$b - vt_1 = \frac{d}{2}\left(1 + m \sin \omega t_1\right) \tag{3}$$

and ends when $y_3 = 0$, or when

$$t_2 = \frac{b}{v} \tag{4}$$

The value of T_1 is therefore given by

$$t_2 - t_1 = \frac{d}{2v}\left(1 + m \sin \omega t_1\right) \tag{5}$$

The exposure T_2 starts when $y_3 = 0$ and ends when $y_3 = y_2$, or

$$b - vt_3 = -\frac{d}{2}\left(1 + m \sin \omega t_3\right)$$

The exposure T_2 is therefore given by

$$t_3 - t_2 = \frac{d}{2v}\left(1 + m \sin \omega t_3\right) \tag{6}$$

Upon multiplying equations *5* and *6* by ω, and rearranging the terms, the equations take the form

$$\omega t_1 - \omega\left(t_2 - \frac{d}{2v}\right) = -\frac{m\omega d}{2v} \sin \omega t_1 \tag{7}$$

and

$$\omega t_3 - \omega\left(t_2 + \frac{d}{2v}\right) = \frac{m\omega d}{2v} \sin \omega t_3 \tag{8}$$

The solutions desired are those that express the quantities t_1 and t_3 in terms of the time t_2 at which the point on the film under consideration crosses the axis OT.

Equations *7* and *8* are of the general form

$$x - y = a \sin x$$

Since x and y are odd functions of each other, $(x - y)$ may be expressed as a Fourier series in y, containing only sine terms. Thus, setting

$$x - y = \sum_{n=1}^{n=\infty} C_n \sin ny$$

where

$$C_n = \frac{1}{\pi} \int_{-\pi}^{\pi} (x - y) \sin ny \, dy$$

the coefficients C_n take the form

$$C_n = \frac{2}{n} J_n(na) \tag{9}$$

where the $J_n(na)$ are Bessel functions defined by the series

$$J_n(na) = \frac{(na)^n}{2^n \cdot n!} \left[1 - \frac{(na)^2}{2(2n + 2)} + \frac{(na)^4}{2\cdot 4(2n + 2)(2n + 4)} \cdots \right] \tag{10}$$

The solutions for t_1 and t_3 thus take the forms

$$t_1 = \left(t_2 - \frac{d}{2v}\right) + \frac{2}{\omega} \sum_{n=1}^{n=\infty} \frac{1}{n} J_n\left(-\frac{n\omega md}{2v}\right) \sin n\omega\left(t_2 - \frac{d}{2v}\right) \tag{11}$$

and

$$t_3 = \left(t_2 + \frac{d}{2v}\right) + \frac{2}{\omega} \sum_{n=1}^{n=\infty} \frac{1}{n} J_n\left(\frac{n\omega md}{2v}\right) \sin n\omega\left(t_2 + \frac{d}{2v}\right) \tag{12}$$

and the total track exposure, $T_1 + T_2$ becomes

$$T_0 = \frac{d}{v} + \frac{2}{\omega} \sum_{n=1}^{n=\infty} \frac{1}{n} \left[J_n\left(\frac{n\omega md}{2v}\right) \sin n\omega\left(t_2 + \frac{d}{2v}\right) - J_n\left(-\frac{n\omega md}{2v}\right) \sin n\omega\left(t_2 - \frac{d}{2v}\right)\right] \tag{13}$$

This result may readily be put into the form

$$T_0 = E_0 + E_1 \sin \omega t + E_2 \cos 2\omega t + E_3 \sin 3\omega t + \ldots \tag{14}$$

where

$$
\begin{aligned}
E_0 &= \frac{d}{v} \\
E_1 &= \frac{4}{\omega} J_1\left(\frac{\omega m d}{2v}\right) \cos \frac{\omega d}{2v} \\
E_2 &= \frac{2}{\omega} J_2\left(\frac{\omega m d}{v}\right) \sin \frac{\omega d}{v} \\
E_3 &= \frac{4}{3\omega} J_3\left(\frac{3\omega m d}{2v}\right) \cos \frac{3\omega d}{2v} \\
&\text{etc.,}
\end{aligned}
\tag{15}
$$

the solution being valid as long as the maximum rate of change of the slit-image width is lower than the velocity of the film.

From this solution for the sound-track exposure, it is apparent that the application of a single frequency to the light-valve results in an exposure of complex wave-form, the distortion components that arise being functions of the fundamental recorded frequency, the unmodulated slit-image width, the percentage of modulation, and the uniform film velocity.

If the over-all gamma of the sound print is equal to unity, the print track wave-form is exactly the same as that of the negative exposure. If, however, the print over-all gamma differs from unity, the print track wave-form must be determined from the following expression for print transmission:

$$T_p = K(E_0 + E_1 \sin \omega t + E_2 \cos 2\omega t + \ldots)^{\gamma_0} \tag{16}$$

where

K is a constant
γ_0 is the over-all print gamma.

Expanding equation *16* as a Taylor's series about the point E_0, there results:

$$T_p = E_0^{\gamma_0} + \gamma_0 E_0^{\gamma_0 - 1}\left(E_1 \sin \omega t + \ldots\right) + \frac{1}{2!}\gamma_0\left(\gamma_0 - 1\right) E_0^{\gamma_0 - 2}\left(E_1 \sin \omega t + \ldots\right)^2 + \ldots$$

from which the ratio of second harmonic to fundamental is found to be approximately given by:

$$H_2 = \frac{E_2}{E_1} - \frac{1}{4}\left(\gamma_0 - 1\right)\frac{E_1}{E_0} \tag{17}$$

To a similar order of approximation the ratio of third harmonic to the fundamental is given by:

$$H_3 = \frac{E_3}{E_1} + \frac{1}{4}\left(\gamma_0 - 1\right)\frac{E_2}{E_0} \tag{18}$$

When the unmodulated slit-image width is restricted to 0.5 mil, and the film velocity to 18 inches per second, as is customary in normal recording practice, the argument $\omega d/2v$ appearing in the coefficients of equation *15* is of such magnitude that the Bessel functions may be replaced by the first term of the series *10* defining these functions. Employing this approximation, the ratio E_2/E_1 becomes

$$\frac{E_2}{E_1} = \frac{m\omega d}{4v}\,\frac{\sin\dfrac{\omega d}{v}}{\cos\dfrac{\omega d}{2v}}$$

which becomes further simplified upon setting

$$\frac{\sin\dfrac{\omega d}{v}}{\cos\dfrac{\omega d}{2v}} = \frac{\omega d}{v}$$

to the value

$$\frac{E_2}{E_1} = m\left(\frac{\omega d}{2v}\right)^2$$

By similar substitutions the ratio of E_1/E_0 is given to a good order of approximation by $E_1/E_0 = m$.

Equation *17* may therefore be written in the simple form

$$H_2 = m\left[\left(\frac{\omega d}{2v}\right)^2 - \frac{1}{4}\left(\gamma_0 - 1\right)\right] \tag{19}$$

while *18*, by similar substitutions, becomes

$$H_3 = \frac{m^2}{4}\left(\frac{\omega d}{2v}\right)^2\left[\left(\gamma_0 - 1\right) + \frac{3}{2}\cos\frac{3\omega d}{2v}\right] \tag{20}$$

these equations being accurate to within 3 per cent for all fundamental frequencies up to about 5000 cps., and for values of γ_0 lying between 0.8 and 1.25.

Examination of these expressions for H_2 and H_3 indicates that low-frequency distortion is largely caused by departures of the over-all print gamma from unity, while at the higher recording frequencies the distortion components are largely due to the action of the light-

valve. Fig. 2 indicates the theoretical values of print distortion for a 0.5-mil slit image and for over-all gammas of 0.85, 1.00, and 1.15, these curves being based upon equations *19* and *20*.

EXPERIMENTAL DISTORTION DATA

The theoretical values of distortion as indicated by the curves of Fig. 2 attain values considerably in excess of those that would ordinarily be tolerated in any of the amplifier equipment associated with either sound recording or reproducing channels. In view of this

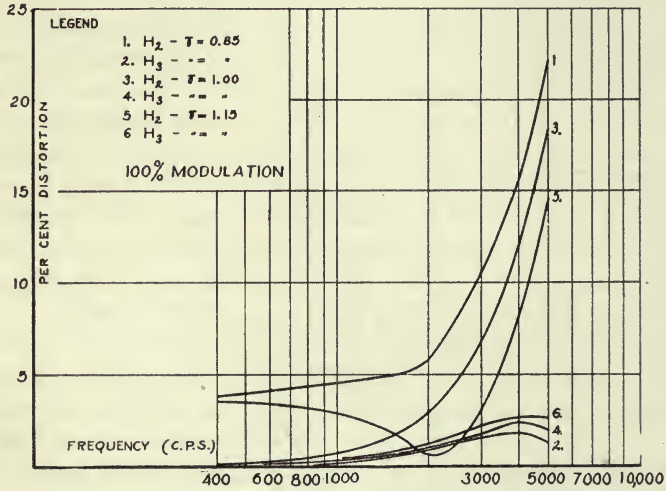

FIG. 2. Theoretical distortion due to effect of ribbon velocity and over-all print gamma.

fact, it becomes a matter of some interest to determine the degree of distortion actually found in sound prints recorded and processed with typical recording and laboratory equipment. To this end, a number of frequency film recordings were made under such conditions as to render the signal input to the light-valve terminals substantially free of all harmonics other than the fundamental. Light-valve ribbon spacings of 2.0, 1.0, and 0.5 mil, resulting in unmodulated slit-image widths of 1.0, 0.5, and 0.25 mil were employed during the tests. The exposures were so chosen as to result in unmodulated visual diffuse negative track densities of approximately 0.55, the development being carried to Eastman time-scale gammas lying

between 0.36 and 0.39. Sensitometric data obtained during the course of development of the test indicated a sufficiently extended straight-line portion on the negative H&D characteristics to accommodate readily the range of density attained in the modulated sections of the negative. The positive H&D characteristics, however, showed such a limited truly straight-line portion as to indicate the necessity of very careful choice in unmodulated print density if characteristic curvature distortion were to be avoided.

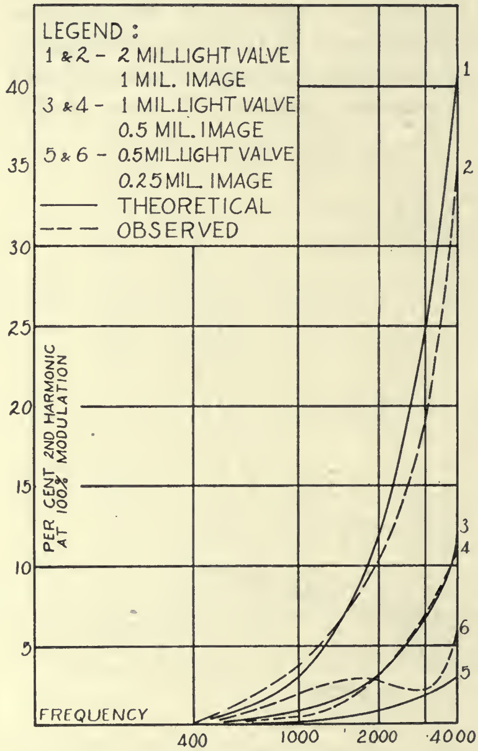

FIG. 3. Theoretical and observed values of second-harmonic distortion due to ribbon-velocity effect.

Prints from the negatives were exposed so as to result in visual diffuse print densities lying between 0.72 and 0.85, several different values of print control gamma being requested.

The first "take" on each negative comprised a dynamic over-all gamma test, following the general method outlined by Albin.[2] This test consisted in making a series of recordings of a constant-level 400-cycle tone, approximately 25 db. below unbiased light-valve overload, at a series of valve-ribbon spacings varying from an equivalent of 20-db. noise reduction to 4-db. noise addition, in seven equal logarithmic steps. The over-all projected print gamma was determined in each case from calculations based upon the variation in reproduced levels from the several steps of the test. Because of the apparent accuracy and simplicity of the test, the over-all print gammas of each distortion test print were checked by this method.

The distortion test portion of each test recording consisted of 20-ft. recordings of the following frequencies: 400, 1000, 2000, 3000, 4000, 5000, 6000, 7000, and 8000 cps. The percentage of track modulation was held constant for all frequencies on any one test, but varied from test to test between the limits of 25 and 90 per cent.

Upon receiving the various tests from the laboratory, the prints were reproduced through a standard Western Electric sound-head and amplifier system, volume indicator readings of the relative levels of the several sections of the print being obtained to permit the determination of over-all gamma of the print and the frequency response characteristic of the complete reproducing system. A band-pass filter was inserted into the reproducing amplifier system during the observations on the dynamic over-all gamma tests to eliminate errors in readings due to film ground-noise components.

Following these measurements on the prints, 8-ft. loops were made of sections of the prints for purposes of distortion analysis. The fundamental loop frequencies employed were 400, 1000, 2000, 3000, and 4000 cps. The loops were reproduced by the same equipment used for determining the print and system frequency characteristics, the output of the reproducing amplifier system being suitably attenuated and applied to the input of a type *636-A* General Radio wave analyzer. The distortion percentages determined in this manner were finally corrected for the relative losses in reproduction of the fundamental and the harmonics as determined from the over-all print and system characteristic.

The curves of Fig. 3 indicate the general agreement between the theoretical and observed values of distortion for the three values of light-valve ribbon spacing employed. Each experimentally determined curve represents the averaged data of a minimum of five sets of distortion test prints, all data having been corrected for the actual over-all print gamma, and expressed in terms of a gamma of unity. It will be noted that the observed values of distortion for the case of the 0.25-mil slit image depart considerably from the theoretical values, the reason for this being yet undetermined.

Fig. 4 indicates the observed relation between the percentage of track modulation and the percentage of second-harmonic distortion for the case of a 4000-cycle fundamental. The linearity of the curve indicates very good agreement with the theory.

In general, the values of third-harmonic distortion obtained were very much higher than those predicted by the theory. Table I

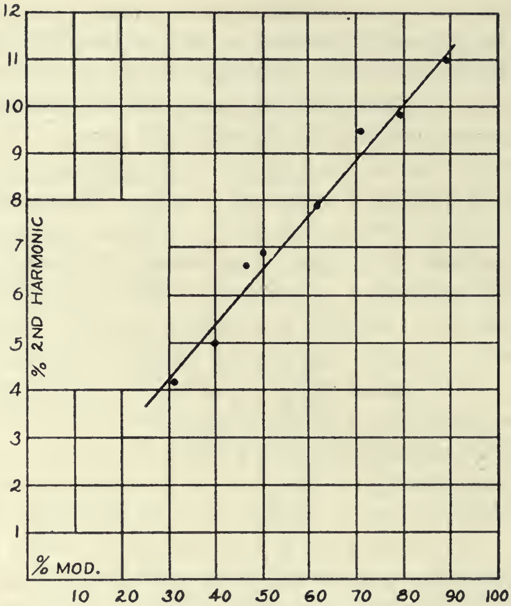

FIG. 4. Relation between percentage of track modulation and observed second-harmonic distortion for 4000-cycle fundamental (1-mil light-valve).

indicates the average values obtained for the case of a 0.5-mil slit image, under conditions of 80 per cent track modulation and an over-all gamma of unity.

TABLE I

Average Values of Third-Harmonic Distortion for 0.5-Mil Slit Image

Fundamental Recording Frequency	Theoretical Percentage of Third Harmonic	Observed Percentage of Third Harmonic
400	0.029	1.06
1000	0.177	2.16
2000	0.710	3.06
3000	1.200	3.88

It is believed that at least a portion of the discrepancy between the predicted and the observed results may be charged to directional effects in the laboratory developing machines. The sensitometric strips attached to each distortion test negative and print indicated small, though definite, directional effect characteristics. Because of the extreme difficulty of treating the action of this effect upon the

developed wave-form, no effort has been made to account for the magnitude of the distortion from this source.

During the course of this distortion study, it was found that many of the print dynamic over-all gamma tests exhibited pronounced variations in gamma throughout the range of density normally believed to lie on the straight-line portion of the positive H&D curve. This was particularly true for those prints so exposed as to result in unmodulated track densities of approximately 0.70 to 0.75. Distortion measurements made on such prints invariably indicated values of second- and third-harmonic content that were excessively high, Table II indicating a typical set of data from such a print.

TABLE II

Variable Gamma Print Distortion, 0.25-Mil Light-Valve Slit Image, 50 Per Cent Modulation

Frequency	Per Cent Second Harmonic	Per Cent Third Harmonic
400	2.38	1.30
1000	2.13	1.61
2000	4.20	1.68
3000	7.77	2.09
4000	10.10	..

Obviously, it would be an error to include data from such prints with those intended to check the distortion introduced by the light-valve. Rather, the value of such data lies in the indication that it affords of the extremely limited range of unmodulated print density that may be employed if print distortion is to be kept at a minimum. Still more so, however, such data indicate in a general way a fundamental difficulty present in any system of variable-density sound recording, because, regardless of the degree of excellence attained by the recording mechanism itself, the fidelity of the final prints obtained is limited by the degree of linearity that may be preserved between variations in negative exposure and corresponding variations in print transmission. It may be argued that push-pull recording would limit such distortion to negligible values, and such might be the case if it were not for the fact that the third harmonic is likely to be quite as objectionable when augmented by push-pull action as the second and third harmonics obtained solely from standard track.

CONCLUSION

General agreement between the theoretical and experimentally determined values of distortion due to the action of the light-valve has been attained. From a practical standpoint, it seems likely that such distortion is reduced to negligible values when a 0.5-mil ribbon spacing is employed in recording. While the curves of Fig. 3 indicate appreciable values of high-frequency distortion even in the case of the 0.5-mil ribbon spacing, it must be remembered that the normal loss of efficiency in reproducing the higher frequencies is at present so great that the sound energy due to the high-frequency distortion components may be relatively low compared to that of the fundamental frequencies. It is, in fact, often found desirable to suppress the reproduction of any frequencies above 7500 or 8000 cps. by the use of suitable low-pass filters, this in itself being some indication of a loss of fidelity in recording at the higher frequencies.

A second factor tending to lessen somewhat the evils of high-frequency print distortion is found in the nature of the normal spectral distribution of energy in speech and music. The probability of the occurrence of high-energy-level, high-frequency components in the complex wave-forms comprising speech and musical tones is small as compared to that existing for the lower-frequency components.

Distortion arising from non-linearity in the relation between negative exposure and print transmission appears to be fully as serious at all frequencies within the recording range as the distortion that might be attributed solely to the recorder modulating device. This is especially true in those cases where release print densities are varied from scene to scene for purposes of print volume control.

Although no data have been presented to indicate the order of magnitude of distortion components of higher order than the third harmonic, measurements on several of the test prints indicated that their magnitude was quite negligible.

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[2] ALBIN, F. G.: "A Dynamic Check on the Processing of Film for Sound Records," *J. Soc. Mot. Pict. Eng.*, **XXV** (Aug., 1935), No. 2, p. 161.

STEREOSCOPY ON THE SCREEN*

L. LUMIÈRE**

Summary.—*Experiments conducted for the purpose of achieving stereoscopic effects upon the screen are based upon projecting the stereoscopic pairs to the screen through red and green filters such that equal quantities of energy will be transmitted to the eyes of the observer, which are fitted with spectacles of the two colors. It is stated that this means avoids the eye-strain attendant upon other methods.*

Investigators have long been interested in the idea of obtaining on the screen by projection the effect given by the stereoscope. I shall not undertake to mention the many solutions that have been suggested, which, with the exception of Lippman's integral photography and Ives' experiments, lead only to a pseudostereoscopic effect because they are based upon a single direction of sight. I shall limit myself to reminding the reader that Rolhmann and d'Alméida were the first to obtain real stereoscopic effects upon the screen.

In 1855, at a meeting of the Académie des Sciences, d'Alméida showed upon the screen images giving the impression of the third dimension, produced by superposing upon the screen the two images of a stereoscopic pair by means of red and green beams, respectively, the spectator being supplied with glasses of the same hues.

Following these experiments, many endeavored to achieve the same effect with beams of colors more or less complementary, sometimes yellow and violet, at other times orange and blue. None of these solutions, however, corresponded exactly to what is really needed in order to avoid eye-strain when looking at these stereoscopic pictures.

The d'Alméida results remain the most interesting, so far as the eye-effect is concerned; it has been applied in theaters to the projection of silhouettes and shadow-pictures giving the sensation of relief. Frequently, the process has been erroneously referred to as "anaglyphs," this word having been coined in 1911 by Ducos du

* Presented at the Spring, 1936, Meeting at Chicago, Ill.

** Paris, France.

Hauron who applied it to a similar but subtractive process, whereas the use of colored light proceeds by addition.

The writer has attacked the problem from a new angle, taking into consideration the fact that red and green rays act differently upon the eye, especially so far as the persistence of the retina is concerned. This difference in reaction was pointed out long ago by Helmholtz for rays of wide variation in wavelength. I had occasion to confirm this difference for red and green rays in an experiment which I reported in a paper to the Académie des Sciences in 1918, and which was the result of a chance observation, which was as follows: if, in a photographic laboratory lighted by a ruby light, one stands near the safelight lantern and looks at a watch fitted with a phosphorescent dial (zinc sulfide plus radium), and then moves the watch slightly but quickly, he will be surprised to note that the figures seem to travel a slight distance over the surface of the watch relatively to its rim, just as if they were not held fast to the face of the watch but connected by means of flexible links. It results from this physiological phenomenon that when two images are projected upon the same screen, one by means of a red beam and the other by means of a green beam, it is impossible to obtain a sensation of steady white, and, furthermore, eye-strain soon becomes unbearable.

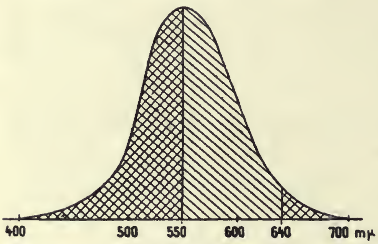

Fig. 1. Gibson and Tyndall response curve.

In order to prevent these disturbing effects, I thought that if it were possible to receive red and green rays in each eye simultaneously, and as it is necessary to blind the left eye to the right image and *vice versa*, the strain would thus be overcome provided the amount of light energy received by both eyes were the same.

To accomplish those two conditions, I used the well known curve drawn by Gibson and Tyndall, which shows a maximum toward 5550 Å. For one of the eyes, I chose on the curve, as seen in Fig. 1, a band embracing apparently the same amount of red and green, and measured with a planimeter what would have to be the boundaries in order that the included surface equal half the total surface comprised between the whole curve and the axis of abscissas. I came to the conclusion that the transparency of one filter should be limited by the

section lying between 5500 and 6400 Å, and that the other filter should let pass freely, on the one hand, the portion between 4000 and 5500 Å and, on the other, the portion between 6400 and 7000 Å.

The manufacture of such filters has presented great difficulties as regards the choice of the coloring medium; but the desired result was

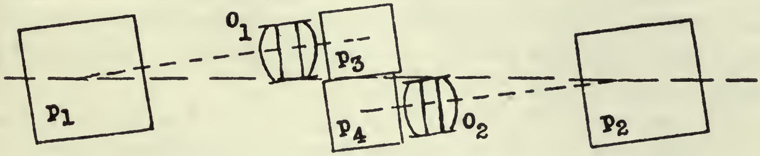

FIG. 2. Arrangement for producing stereoscopic pairs on the film.

finally achieved and images were projected upon the screen that looked like ordinary black-and-white pictures but which could be viewed for several hours without eye-strain.

The first of the two filters thus obtained is light yellow, and the second looks like pure blue. The difficulty in selecting the dyes rested on the fact that the dyes had to show the least possible non-selective absorption and as sharp as possible limits on the edges of absorption.

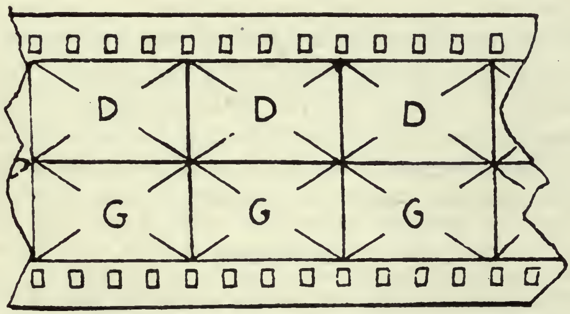

FIG. 3. Arrangement of stereoscopic pairs on the film.

These conditions were fulfilled by mixing naphthol green, tartrazine, and eosine for the first filter; and, for the other filter, by joining a blue cyanol tinted glass to another glass tinted with diethylmeta-aminophenol sacchareine, it being impossible to mix the latter dyes owing to the fact that one is acid and the other basic.

Having produced good stereoscopic still pictures, I next tried to apply the principle to motion pictures. The experimental device utilized is shown in Fig. 2.

The two pictures forming the stereoscopic pair are printed upon the same film, which runs horizontally so as to produce an image practically similar to the one used in monocular vision, losing as little as possible of the sensitized surface.

In this apparatus, reflecting prisms p_1 and p_2, whose principal sections are slightly bent toward the horizontal plane passing through their centers, reflect the light-beams through the lenses O_1 and O_2. The beams then pass through the prisms p_3 and p_4, producing the images D and G as shown in Fig. 3.

When projected, the film runs in front of two lenses, whose axes are parallel and are cut by a plane parallel to the axis, in order to allow homologous centers of the projected images to register in height when the distance between the principal axes is made to vary, the registering of horizontal parallaxes being effected by moving horizontally one of the lenses parallel to its principal axis. In front of the two lenses are located the colored filters described above, and the spectators are supplied with spectacles of the same hues.

The stereoscopic effect is then complete, and the spectator is unable to estimate his distance from the screen. It seems to him that he is in front of an open window, and that the actors are moving within the very room.

The tremendous difficulties involved in the solution of processes avoiding the need of placing between the spectator and the screen a selecting device, to prevent the two eyes from seeing simultaneously the two images of the stereoscopic pair, have led me to the conclusion that the process described here, which produces striking effects, will lend itself to practical application in theaters in the near future.

DISCUSSION

MR. TASKER: A method more or less similar to this, but which does not involve an intervening device to give the eye selective vision, has been proposed, but it is one that will probably never be developed because of the great likelihood of severe eye-strain. The two eyes are separately flooded with light of colors complementary to the colors intended to be seen, so that the eyes will, in effect, be blinded by the intensity of the light. For example, a strong red light would be projected across the theater so it would be seen by the right eye and be outside the line of vision of the left; with a strong green light from the other side, seen vividly by the right eye and yet out of sight of the left. The ensuing blindness to those respective colors would permit the alternate images to be seen upon the screen. Very probably this can not be done without severe eye-strain.

MR. RICHARDSON: Has any real progress been made recently in stereoscopy, in a way that would permit it to be commercialized in the theater?

MR. TASKER: The answer to that depends upon personal opinion, as to whether or not a method that requires that the spectators wear spectacles of some sort is commercially admissible.

MR. RAYTON: If I understood the paper by M. Lumière, the point is made that the source of eye-strain in viewing pictures projected through two colors, which for convenience may be called "anaglyphs," is found in the phenomenon that he discovered—the apparent shift of figures upon a watch face. That is news to me. Whether there is any significance to the observation in this connection, I do not know. However, there are certainly other sources of eye-strain involved in projection of that kind, and whether the expedient of selecting two filters calculated to transmit equal quantities of energy to the eyes of the observer will overcome the entire difficulty, I very much doubt. One of the difficulties, of course, is the chromatic aberration of the eye because of which the images due to lights of various wavelengths or colors fail to come to the same focus. For example, any images of a distant object seen through a blue filter will look out of focus to people with normal vision. That has been one of the difficulties in this kind of projection, I am sure. My own personal experience confirms the statement.

Another difficulty in viewing anaglyphs is that of rivalry between the two colors. It is my personal experience, for example, that one minute I see the red picture, and the next minute the green; then possibly the next instant the two may fuse together into reasonable white. What is the cause of that I do not know. Of course, it is common knowledge among ophthalmologists that there is such a thing as the suppression of one eye or the other in ordinary binocular vision. That occurs, they say, rather commonly and frequently. It may be that something of that sort is involved. I wish merely to make the point that I can hardly conceive that the solution proposed will overcome all the difficulties of achieving comfortable vision with stereoscopic projection of this kind.

MR. RICHARDSON: So far as I am able to observe, the stereoscopic effect seems to be enormously exaggerated.

MR. RAYTON: That is a question of geometry, and probably is deliberate, in order to be sure that everybody sees the effect. It is not necessary. If the points from which the two pictures are taken are properly chosen, and the distance from the observer to the screen is taken into account in designing the projector, perfectly normal stereoscopy, or what we might call "orthostereoscopy," can result. The same will be true of the polaroid or any other type of stereoscopy. To get a true reproduction of three dimensions one must take into consideration the geometry of the situation.

MR. TASKER: A similar comment can be made as to color. When color first reached the screen it was very much overdone, in the attempt to make the public very definitely color-conscious, as it were. To my mind, the more esthetic efforts are those in which the color reaches into the consciousness, so that one realizes presently that the scene is more natural than it would have been in black and white. In this respect the polaroid method, requiring glasses or the equivalent, seems the most promising because it permits the projection of full color as well as stereoscopic vision.

MR. KELLOGG: Mr. Rayton spoke about the suppression of one of the images of the red-and-green system. I happen to have had a certain muscular eye trouble such that under certain conditions I can not make the two images coincide.

When the two images are some distance apart, the suppression of one or the other is entirely under my control, and I can switch back and forth from one to the other at will. It takes perhaps a second or two to adjust my attention and bring the previously suppressed image up to full consciousness. The other image goes out at about the same time.

Another point is of some interest: I have played a little with red-and-green stereoscopy, with shadows—an old toy. It is quite amusing to reverse the glasses. Somebody behind the screen would lift up a small chair and turn it around. The chair would seem to be well out in front of the screen, and one would feel as if he could unhesitatingly and without error touch any part of it. When the chair was rotated, the impression would be that of a perfectly normal chair—just a black chair, or the silhouette of one. The third dimension was very vivid. Now, when the glasses were reversed the chair would immediately become an india-rubber chair, tremendously distorted in shape. The near parts would be small and the far parts larger. When it was rotated, it would seem to be made of rubber, and would undergo weird contortions. If a person would hold out his hands near the screen, there would be a vivid impression of his having a tremendous right hand and a tiny left hand.

If the stereoscopic or binocular effect is good, the mind automatically places more confidence in it than in the perspective. When the two effects work together, one has the impression that everything is normal; but when they are opposite, he disregards whatever opposing third-dimensional effect he might get through perspective, and feels that the object he is looking at is grossly misshapen.

THE ELECTRON-IMAGE TUBE, A MEANS FOR MAKING INFRARED IMAGES VISIBLE*

G. A. MORTON**

Summary.—*The construction and theory of operation are described of the electron-image tube, which consists of a photosensitive cathode, a fluorescent screen, and an electron optical system which focuses the electron "image" from the cathode upon the viewing screen. Due to the wide spectral response of the cathode, the tube can be used to convert infrared, visible, or ultraviolet images into visible images upon the fluorescent screen.*

The electron optical system is discussed and its analogy to the conventional optical system is shown. To reproduce an image faithfully the electron "lens" system must be corrected for various aberrations. Methods of making these corrections are indicated, and applications of the device are described.

Considerable interest is attached to the study of images formed by radiations in the invisible portions of the spectrum. Images formed in these spectral regions can, in general, be made visible by photographic methods. The intervention of a photographic process, however, necessitates a certain lapse of time between receiving the image and viewing it. Often it is desirable to be able to view an image continuously while it is being received.

In the case of an ultraviolet image, continuous observation can be accomplished by the use of fluorescent screens. Infrared images can not, however, be made visible by this means. To make an infrared image continuously visible, it is necessary to resort to electrical methods. Certain television systems are capable of rendering continuously visible an infrared image, but, however, involve elaborate and complicated equipment.

The electron-image tube[1] is a second and much simpler instrument for accomplishing the same results. It consists of a photosensitive cathode, a fluorescent screen, and an electron optical system to focus upon the fluorescent screen the electrons from the cathode. The cathode is so sensitized that it will emit electrons when illuminated

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*Presented at the Spring, 1936, Meeting at Chicago, Ill.

**RCA Manufacturing Co., Camden, N. J.

by radiation, which may be ultraviolet, visible, or infrared. If an image is projected upon the cathode, electrons will be emitted from every point of the cathode surface in proportion to the illumination at that region. Close to the cathode the leaving electrons form an electrical image which is a reproduction of the light image; they are then accelerated to a high velocity and reassembled again into an image at the point at which they strike the fluorescent screen. The method used to refocus the electrons is one of the most interesting aspects of the image-tube and warrants a rather detailed discussion.

In order to refocus the electrons it is necessary to construct the electrical equivalent of an optical lens. Such an "electron lens" is possible because of the similarity between electron paths through a cylindrically symmetrical electrostatic field and those of light rays through a lens. This similarity is, in fact, the basis of the comparatively new science of electron optics.

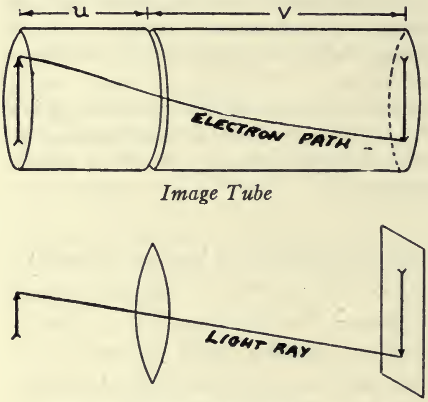

FIG. 1. Arrangement of elementary electron-image tube.

The basis of the "electron lens" in the image-tube is the electrostatic field formed between two coaxial cylinders of equal diameters. The arrangement is shown in Fig. 1, as applied to an elementary image-tube. This lens is familiar to those who have worked in the field of electron optics, and can be shown to have properties similar to those of a thick glass lens. It has two separated principal planes and two focal points, the positions of these elements being dependent upon the velocity of the electrons entering the system and the potentials of the two lens elements. The use of this lens in the image-tube differs from its usual application in that the electrons enter the lens at virtually zero velocity, which fact places one of the focal points and one of the principal planes at the cathode. This, together with the fact that the index of refraction is zero in the cathode region, makes it impossible to apply ordinary optics to the system.

However, it has been possible to calculate the actual potential distribution and the electron paths, and from them to determine the properties of the lens system. These properties have also been de-

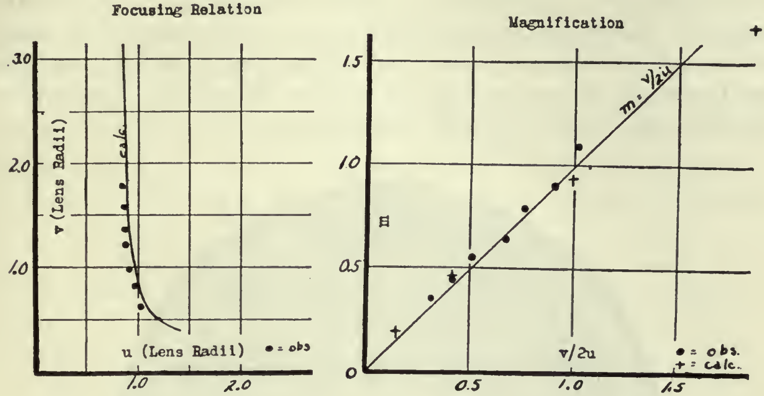

FIG. 2. (*Left*) Relation between cathode-to-lens distance (u) and lens-to-image distance (V); (*right*) relation between these distances and the magnification.

termined experimentally by the use of an image-tube with a movable cathode and screen. The results of the experimental and theoretical investigation are given in Fig. 2. On the left is shown the curve giving

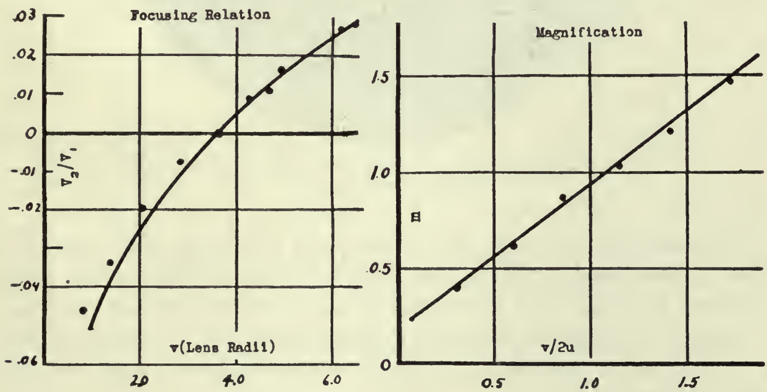

FIG. 3. Relation between ratio of potential of rings and total cathode-to-anode potential, and focal length.

the relation between cathode-to-lens distance, u, and lens-to-image distance, V; on the right, the relation between these distances and the magnification. It is interesting to note that the magnification

is quite accurately given by $V/2u$, rather than V/u, as is the case with the simple glass lens.

The image produced by the lens is inverted, as is the image in the optical analogue. Furthermore, the lens suffers defects that are very similar to those of an uncorrected glass lens. For example, the image field is curved in the same sense; the astigmatism of the lens is similar; and the image shows marked pin-cushion distortion. Methods of correcting these defects will be described later.

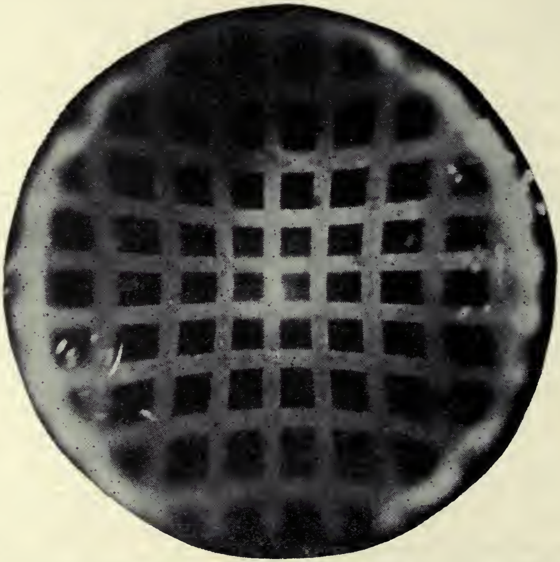

FIG. 4. Showing pin-cushion distortion and blurring, before correction.

The practical difficulty with the system lies in the fact that for a given cathode-to-lens distance there is only one position of the screen for which the image will be exactly in focus. It is therefore necessary to mount the elements extremely accurately or to construct a tube in which the elements are movable. Both these solutions involve difficult constructions.

A much more desirable form of lens is one in which the focus can be varied electrically. One method of accomplishing this is to make the cylinder adjoining the cathode of resistive material, so that a potential gradient can be established between the lens and the

cathode. In actual practice, instead of making the cylinder resistive, it is found sufficient to divide it into a number of rings, each of which is connected successively to a higher potential. The focal length of the system is determined by the ratio of the potential applied to the rings and the total potential between the cathode and the anode. This relation is shown in Fig. 3.

The image produced by the system is shown in Fig. 4. The pincushion distortion and blurring of the image are very evident. Without changing the actual lens system, there are two methods of correcting these defects. The first is to make the cathode of resistive

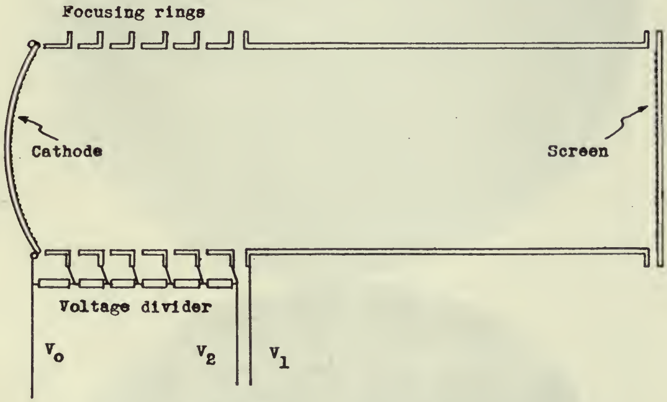

FIG. 5. Image-tube; fixed magnification.

material, so that a radial potential gradient can be established over it; the second is by properly shaping the cathode.

The first method is not at present of much practical importance, although theoretically interesting. The second method, that of shaping the cathode, is used in the image-tube with excellent results. It has been found experimentally that a cathode curved to a radius equal to approximately one lens diameter, combined with the variable-focus electron lens system just described, will produce a flat image with very little aberration or distortion. This construction is illustrated by Fig. 5. A photograph of the image produced by this type of system using the same grid pattern used in Fig. 4 is shown in Fig. 6. It will be seen that the image is free from distortion and is uniformly sharp.

The construction of the photosensitive cathode to be used in a given

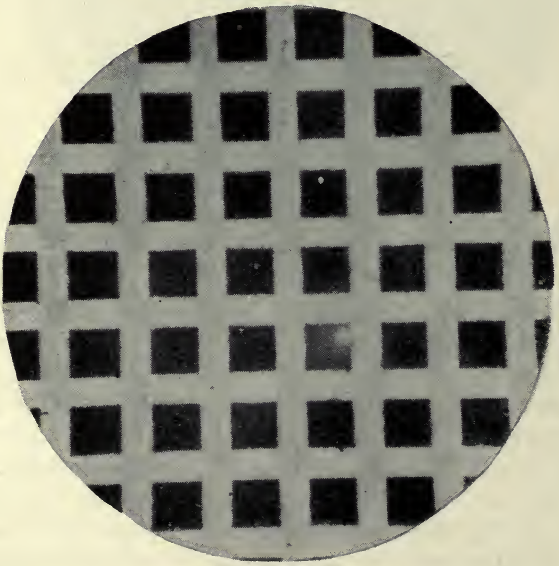

FIG. 6. Image of Fig. 4, after correction.

FIG. 7. Resolution pattern.

FIG. 8. Photograph of image on fluorescent screen.

FIG. 9. Photograph of image on fluorescent screen.

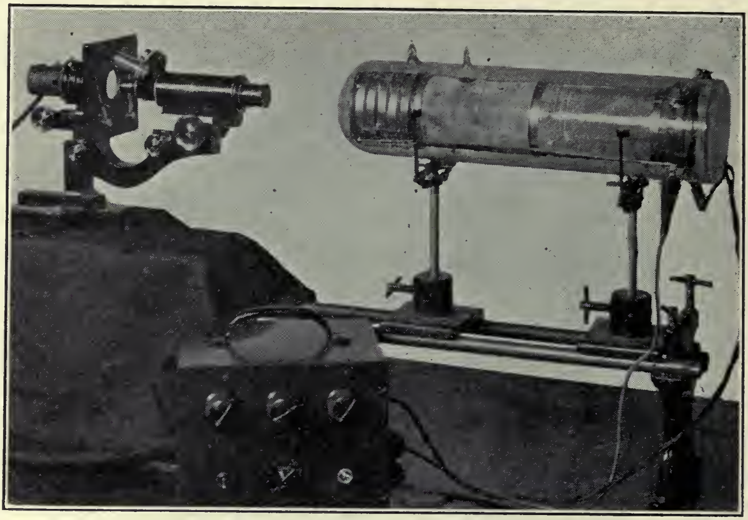

FIG. 10. Image-tube and microscope, arranged for infrared work.

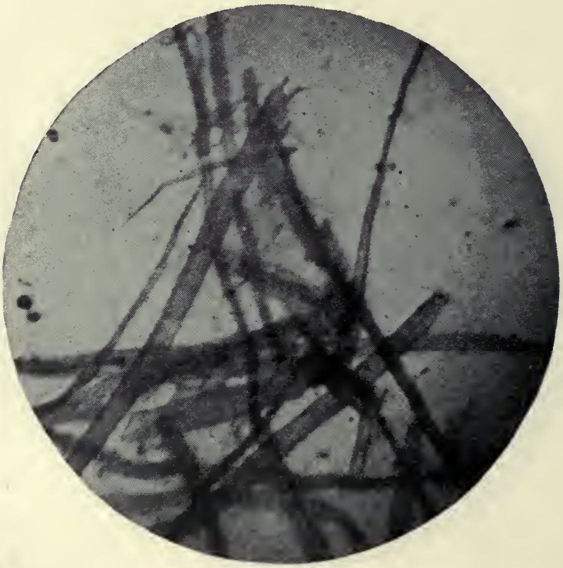

FIG. 11. Visable image of micro-specimen illuminated by infrared light.

image-tube will depend upon the spectral region in which maximal sensitivity is desired. For the visible and infrared portions of the spectrum, a cathode sensitized with cesium on silver oxide is used. This surface is similar to that used in a hard cesium photocell, but is made very thin, so that photo-electrons will be emitted from the face of the cathode when an image is projected upon the opposite side. The resolution of this type of image-tube is about 300 lines, as can be seen from the resolution pattern shown in Fig. 7. This limit is not inherent to the electron lens, but is due to mechanical imperfections of cathode and lens.

In order to illustrate the fidelity of the image, Figs. 8 and 9 show photographs of the fluorescent screen when an infrared picture is projected upon the cathode.

An interesting use to which the image-tube may be put is in connection with infrared microscopy. Fig. 10 shows an image-tube and microscope arranged for infrared work. The visible image of a micro-specimen illuminated by infrared light is shown in Fig. 11.

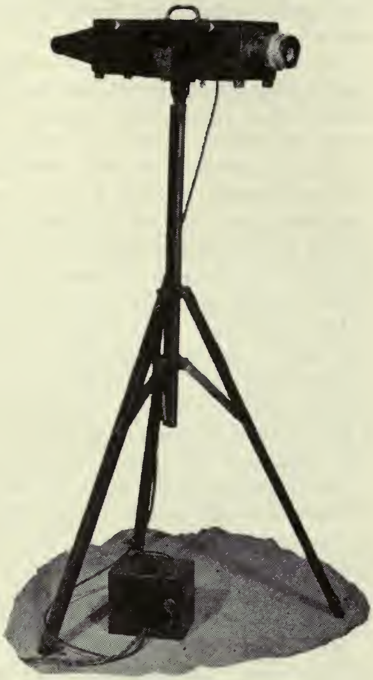

FIG. 12. Electron telescope employing the image-tube.

Another application is illustrated in Fig. 12, which shows an electron telescope in which is used an image-tube. With this instrument, it is possible to see objects illuminated by infrared radiation. Such a device may be used to test smoke and haze penetration by infrared rays, for signalling, *etc.*

Although at present the sensitivity of the image-tube is such that the image is not as bright as the picture projected upon the cathode, there is every reason to believe that the sensitivity will eventually be increased to a point where the image is brighter than the source, a thing impossible in the optics of light.

REFERENCE

[1] ZWORYKIN, V. K., AND MORTON, G. A.: "Applied Electron Optics," *J. Opt. Soc. Amer.*, **26** (April, 1936), No. 4, p. 181.

DISCUSSION

MR. KELLOGG: Mr. Morton spoke of the relative brightness of the original and the fluorescent screen image. What is meant by the "brightness" of the original, when the original is invisible? Also, how much sacrifice of electron emission results from the fact that the light reaches the cathode film through the back instead of striking the front surface directly?

MR. MORTON: The term "brightness" is purely descriptive. A better way of stating what I mean would be to say that the rate at which the fluorescent screen emits radiant energy may be greater than the rate at which radiant energy falls upon the cathode. At present, the ratio of the energies is slightly less than unity.

The absorption of the inert backing of the cathode film is about 50 per cent. The photoelectric emission from the type of cathode used in this tube is less than one-tenth that of a good photocell. Part of this low sensitivity is due to absorption of light going through the film and partly to the nature of the surface itself. We have experimental evidence that the photo-emission from the film of photosensitive material on the cathode may be very greatly increased.

MR. CRABTREE: How is the brightness contrast varied? What is the limit of contrast? Can this be applied to x-ray cinematography ?

MR. MORTON: The cathode is very insensitive to x-rays. It would be very difficult to make an image-tube that could be used in that region of the spectrum. I do not know of any material that is a good x-ray photoelectric emitter. Most substances can emit x-ray photo-electrons, but very inefficiently.

The brightness of the image on the fluorescent screen depends upon the photoemission from the cathode, the magnification, and the over-all voltage on the tube. At present, 4000 volts are used, but it would be possible to obtain a much brighter image if 10,000 volts could be applied.

MR. TUTTLE: Is there any lag with this particular type of screen? If so, how much; and does it increase with the intensity?

MR. MORTON: The phosphorescent lag in the screen is quite small, of the order of $^1/_{25}$ second. The phosphorescent decay is more or less logarithmic.

MEMBER: Is the sensitivity sufficient to use the tube to see, for example, a ship entering a harbor in a fog?

MR. MORTON: The tube will not respond to infrared radiation of wavelengths longer than 10,000 or 11,000 Å. In order to penetrate fog, infrared radiation of wavelengths of 50,000 to 100,000 Å must be used. Therefore this form can not be used for fog penetration. It can, however, be used to see through haze.

MR. WOLF: Will Mr. Morton tell us something about the applications of the optical system?

MR. MORTON: At the present time its application is rather limited. It may be useful in the field of biology, both as a means of examining organisms that would be destroyed by visible light, and of permitting the use of dyes having selective absorption in the infrared. In the form of a telescope it can be used for signalling, identification, *etc.*

NEW MOTION PICTURE APPARATUS

During the Conventions of the Society, symposiums on new motion picture apparatus are held, in which various manufacturers of equipment describe and demonstrate their new products and developments. Some of this equipment is described in the following pages; the remainder will be published in subsequent issues of the Journal.

COPPER-OXIDE RECTIFIERS FOR MOTION PICTURE ARC SUPPLY*

I. R. SMITH**

Ten years ago there were perhaps five fairly important types of small rectifiers. Each had some degree of merit but all possessed certain positive disadvantages that limited their application. Crystal rectifiers, for example, were distinctly limited to handling minute amounts of power, such as in radio detection. Wet electrolytic rectifiers were messy and required maintenance. Vibrating rectifiers got out of adjustment, wore out, were noisy, and caused radio interference. Glass-enclosed rectifiers of all types were inefficient at low voltages, uncertain as to life. Of the last group, the mercury pool had a satisfactory, long life, but was difficult to start, and after it had been started would stop unless a definite minimum current were kept going. The hot-cathode types did not have the latter drawback, but were less satisfactory as to life, particularly for industrial uses. Replacements were definitely needed, at best, several times a year.

With these types in mind, one could have set down readily the requirements for the ideal rectifier as one that did not have the various disadvantages of the then-existing devices. Such a procedure would have resulted in describing the ideal rectifier as one that would be capable of handling any amount of power; that would be preferably metallic; dry; quiet in operation; without moving parts or contacts; free from radio interference; rugged in form; dependable in performance; and economical in operation.

A real need existed for a rectifier with such characteristics. This need became most pressing during the days of direct-current radio because of *A*-battery charging requirements, and by a fortunate turn of events it was just at that time that the copper-oxide rectifier was ready for the market. The first units made were *A*-battery trickle chargers, just 10 years ago. In this field the rectifier found ready acceptance, and literally millions were sold, because it was generally recognized that here was a rectifier that appeared to approach the ideal already described. It was metallic, had no moving parts, was noiseless in operation, set up no radio

* Presented at the Spring, 1936, meeting at Chicago, Ill.

** Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

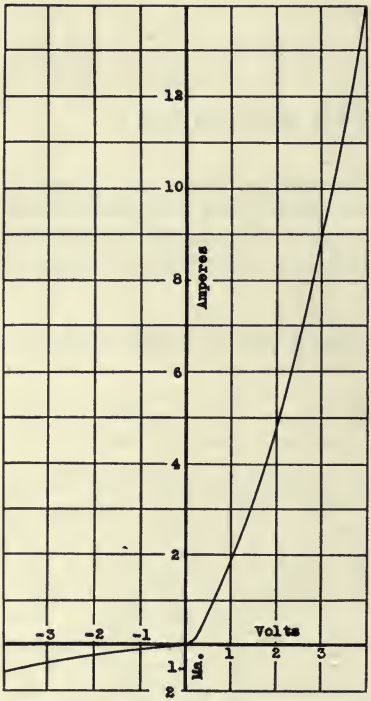

FIG. 1. Voltage-current relation for typical 1.5-inch diameter disk.

interference, was rugged in form and gave promise of long life in operation. The need for such a rectifier proved to be so real that it practically supplanted other types in the radio battery charging field.

It was recognized at the time, of course, that the radio activity was likely to be short-lived, so that if the rectifier were to continue in existence its use would have to be extended into other fields. Intensive study of the rectifier characteristics was then undertaken so that we might know exactly to what extent the rectifier could be applied industrially. A thorough investigation was made of the voltage-current relations in the two directions of conduction, the effect upon these of different temperatures, the limitations as to current-density and voltage gradients, the changes in characteristics as the result of operation and age, as well as many lesser points. The study of the rectifier, its properties, and the process of making it is still going on.

The application of the rectifier to industrial uses, then, has been going

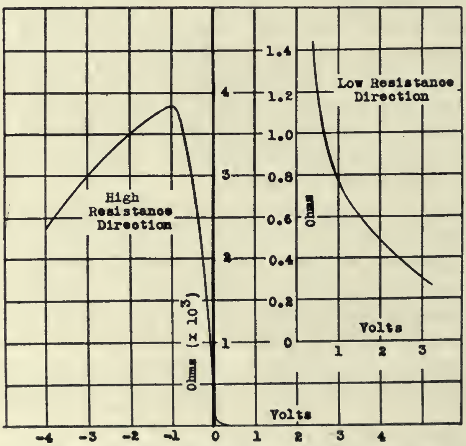

FIG. 2. Voltage-resistance relation for typical 1.5-inch diameter disk.

on for many years, and has proceeded to an extent greater than perhaps is generally realized, until today the copper-oxide rectifier has been accepted as standard equipment in many applications in which reliability and sturdiness are paramount.

RECTIFIER CHARACTERISTICS

Basically, a copper-oxide rectifier is about as simple a piece of equipment as can be imagined. An elementary rectifier in the most usual form consists of a washer of copper, one side of which is covered completely with red or cuprous oxide. Such a washer, provided it has been properly made, has the remarkable characteristics shown in Fig. 1. Here are shown the voltage-current relations in the two directions of conduction of a typical $1^1/_2$-inch diameter disk. In the low-resistance or forward direction, with 3 volts, for example, impressed across the disk, a current of 9 amperes will flow. When the voltage is reversed, the current drops to 1 milliampere, so that the ratio of resistance in the two directions is 9000 to 1. The same data are plotted in Fig. 2 in terms of voltage and resistance.

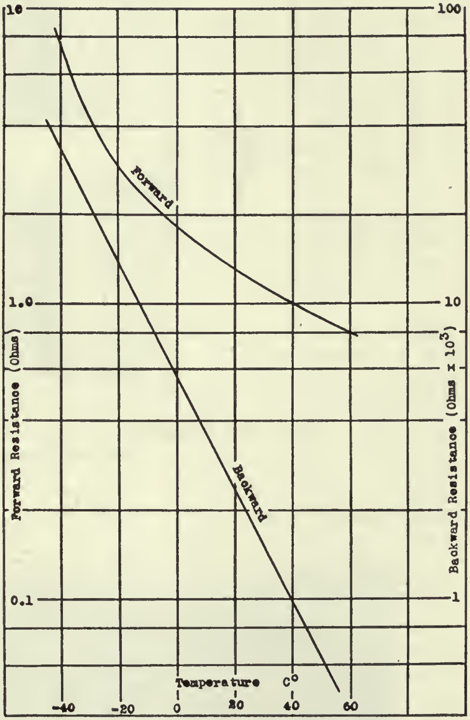

FIG. 3. Resistance-temperature curves for typical 1.5-inch diameter disk, measured at 1.25 volts d-c.

These resistance values are not constants, but are found to vary considerably with the temperature of the washer, and, to some extent, with age. It is important to note that as the temperature changes, the resistance varies, not in the direction one might expect in a device that is about 95 per cent copper, but in the opposite direction. In other words, as the temperature rises, the resistance decreases. The general nature of these changes is shown in Fig. 3, which contains typical resistance curves over a temperature range of −40° to +60°C., for a constant impressed voltage.

Certain changes in these characteristics were found to occur with time, both in the forward and backward directions. In the forward direction the resistance tends to increase as time goes on, the amount of increase depending upon the

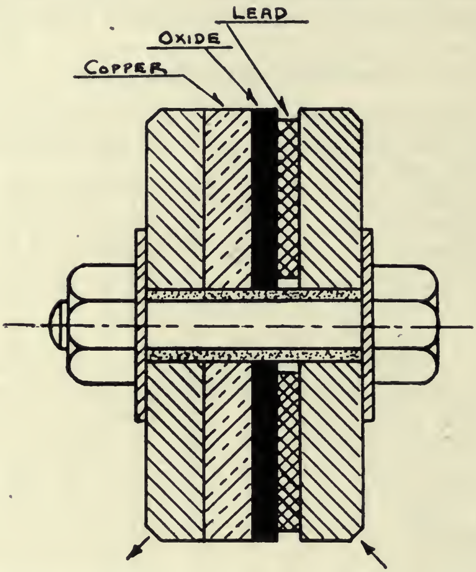

FIG. 4. Exaggerated view of single disk unit construction.

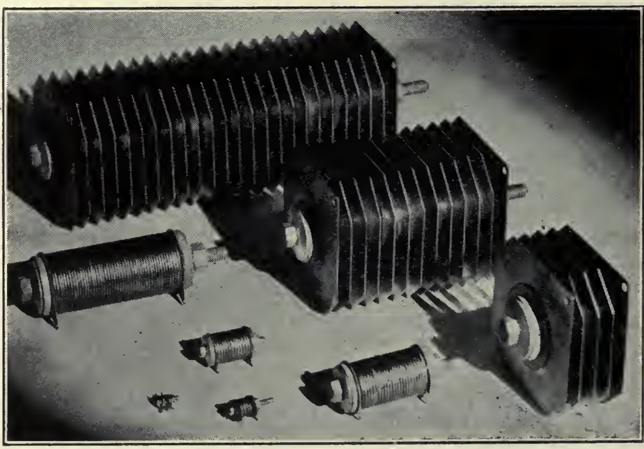

FIG. 5. Typical Rectox units.

temperature at which the rectifier is maintained; the higher the temperature, the greater the change. In the back direction substantially no change takes place except while the unit is in operation, during which time the back resistance decreases.

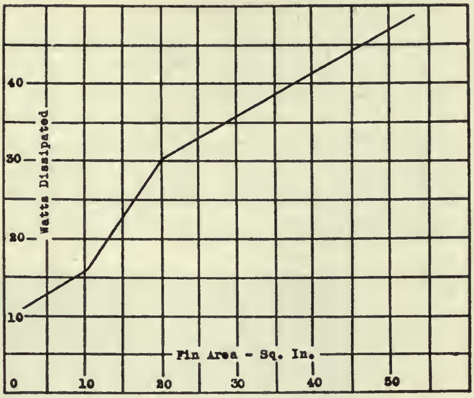

FIG. 6. Effect of increase in area of radiating fins on ability of stack to dissipate heat, showing watts dissipated by 8-inch stacks for 20°C. temperature rise; fins spaced best distance apart.

The characteristics of the washer having thus been determined, the next step is to build the complete rectifier stack. The method of assembly has proved to be rather important. While the copper-copper-oxide washer is a rectifier complete in itself, it was necessary to devise means of getting the current into and out of it. The outside oxide surface has considerable contact resistance, so if a terminal is simply laid upon it the resistance between it and the oxide will be so great that the rectifier will not be able to function properly. So the contact resistance had to be reduced by graphiting the surface with rubbed-in carbon. Furthermore, it was found that the oxide surface was actually not smooth, but was all hills and valleys, so that a hard, flat terminal would contact only part of it. This led to the use of a soft lead washer next to the oxide, forced by pressure into intimate contact with the entire surface of the oxide. Then it was possible to complete the assembly with any suitable terminal, or with more disks or radiating fins, as might be desired. The general construction is illustrated in Fig. 4.

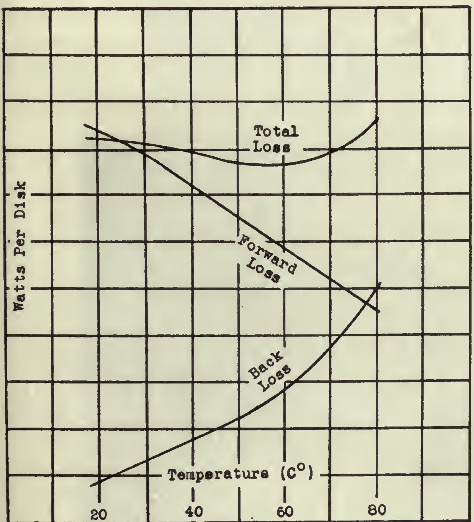

FIG. 7. Variation in total loss at different temperatures.

With such an assembly, it was possible to build up satisfactory units similar to those shown in Fig. 5, but before the units could be applied, methods had to be found for determining what

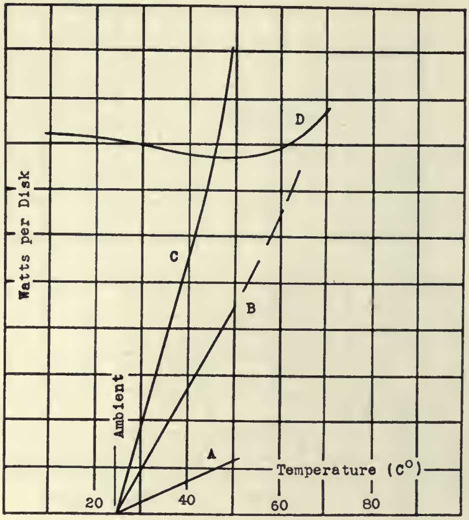

FIG. 8. Comparison of total loss curve at different temperatures with temperature rises of different types of units at various values of watts dissipated: (*A*) unit with no radiating fins; (*B*) unit with 3-inch diameter fins; (*C*) unit with 4-inch diameter fins, fins spaced best distance apart; (*D*) total loss.

electrical ratings could be obtained from them.

BASIS OF RATINGS

Ratings are based primarily upon the fact that the copper-oxide rectifier is a resistance device. Washers will divide the load in parallel, then, inversely as their forward resistance, and in series will divide the voltage directly as the resistance. So it could be said, to begin, that if reasonable care were taken to prevent large differences in washer resistances, washers could be connected in series or parallel to any extent desired. If this had not been possible, obviously the application of the rectifier would have been greatly restricted.

Since the rectifier is a resistance device, it is evident that when current flows through it in the forward direction, or voltage is applied that sends leakage current through in the back direction, there will be I^2R losses that will generate heat in the rectifier. The effect of heat upon the characteristic has already been dis-

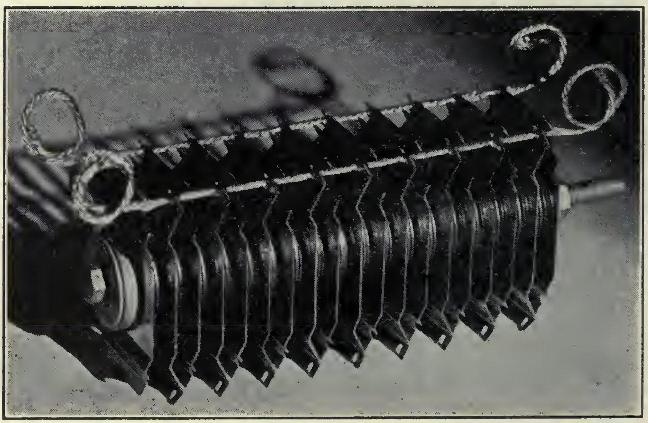

FIG. 9. Single motion picture arc rectifier stack.

cussed, as illustrated in Fig. 3. A study of this characteristic shows that as temperature increases the tendency is for leakage current to increase faster, and evidently if the rise in temperature is not halted, the current in the high-resistance direction may reach dangerous proportions, approaching a short circuit. So the matter of dissipating the heat generated and keeping the rectifier temperature down to a safe value had to be given close attention.

The dissipation of heat losses is, of course, something with which every engineer is constantly concerned. The method adopted here was that of cooling by convection. By using properly sized and spaced radiating fins, it was possible to dissipate the heat and keep the temperature of the units down to a safe point. Fig. 6 compares the performances of radiating fins of various sizes, all spaced the best distance apart, showing how many watts can be dissipated by stacks of disks 8 inches long, the temperature rise in each case being 20°C. For example, if no fins are used, a dissipation of 10 watts will result in the 20° rise. If $2^1/_4$-inch diameter fins are used, the dissipation can be increased to 12 watts; with 3-inch fins to 16 watts; and with 4-inch fins to 31 watts. Thus, by the addition of radiating fins the watts dissipated per stack have been increased three times for the same temperature rise. Since the watts to be dissipated depend directly upon the voltage and current per disk, it follows that the use of fins permits a very considerable increase in the disk rating.

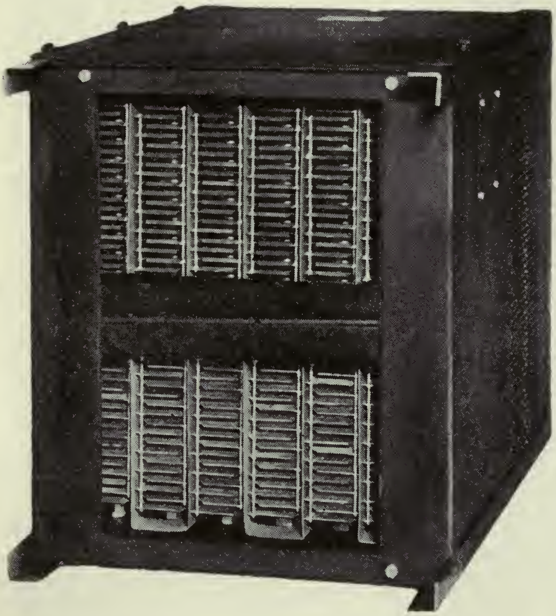

FIG. 10. Arrangement of 12 stacks for 65-ampere, 33-volt output.

This in itself, however, was not sufficient to establish the correct rating. It was necessary to determine also what combination of voltage and current could be used. A given unit operating, for example, with an output of 3 volts and 6 amperes might have substantially the same loss and temperature rise as with an output of 6 volts and 3 amperes; but that alone would not be a sufficient criterion of the correctness of the rating. The final analysis had to take into account the safety of the rating, which depends upon how the losses vary with temperature. That is, the total losses had to be calculated at various operating temperatures, so that their trend would become evident, and this had to be compared to the heat-dissipating ability of the type of unit structure being considered. An example will help to make this clear.

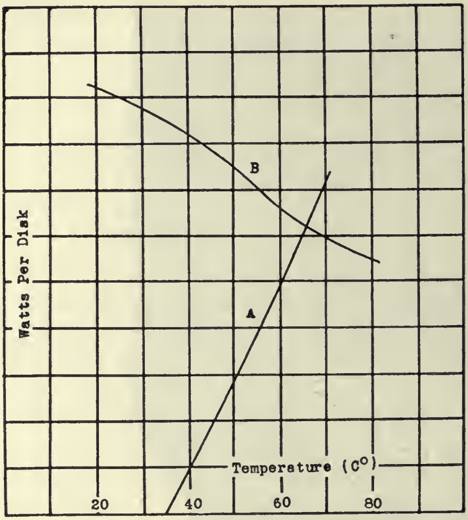

FIG. 11. Comparison of watts loss at different temperatures in motion picture rectifier unit with temperature rise curve of the same unit at different watts dissipation.

Let it be assumed that it is desired to make a bridge type full-wave unit having one disk in each leg, and having a d-c. output of 4.5 volts, 0.5 ampere. The first step would be to calculate the back losses in the unit operating at this output. This is done over a range of operating temperature from 20° to 80°C., and the result is the curve of Fig. 7. This procedure is then repeated for the forward losses, as shown also in Fig. 7. These show the opposite tendency, as is to be expected. The next step then is to add the two loss curves, resulting in the total loss curve of Fig. 7. A minimum point is found at 60°C., which, of course, is the point of maximum efficiency since the same output is assumed throughout.

The final step is to select the unit structure that will be capable of taking care of the losses. This is accomplished as shown in Fig. 8. Three curves are plotted, all originating at 25°C., which is taken as the ambient temperature. These curves are for units with (*A*) no radiating fins, (*B*) with 3-inch fins, and (*C*) with 4-inch fins, each at the best spacing, and show what temperature rise will result in any of these types of structure for various watts per disk dissipated within the unit.

In Fig. 8 is plotted also the total loss curve (*D*) of Fig. 7. The conclusions to be drawn are obvious. Curve *A* shows no intention of coming anywhere near curve *D;* hence a unit with no radiating fins could not be worked at this rating. Curve *B* is approximately tangent to curve *D*. However, a slight rise in ambient temperature, for example, would result in the two curves failing to touch. Curve *C*

crosses curve D almost at right angles, and evidently the ambient temperature could rise considerably and the curves would still intersect.

The 4-inch fin construction then would be selected as suitable for handling such a rating. The unit would operate at the point at which the curves crossed,

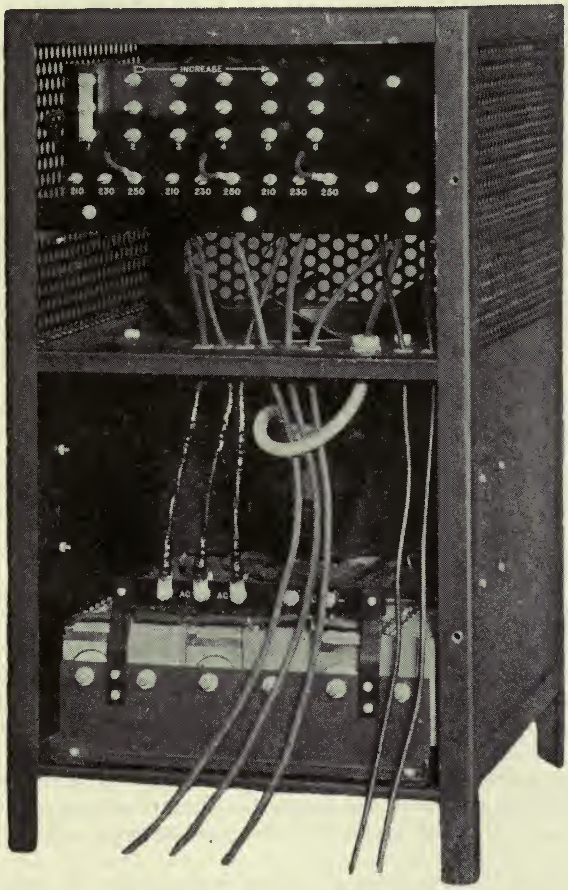

FIG. 12. Complete motion picture arc rectifier for 65-ampere, 33-volt output.

or a rise of 20°C. above ambient. The unit would be quite stable, that is, would have no tendency to run away because of a slight increase of temperature, from whatever cause. Needless to say, the loss calculations must be based upon the unit characteristics after aging, not when new.

By the same method then, any unit rating can be examined and its correctness checked so that all guesswork is eliminated.

FAN COOLING

It will no doubt be apparent from this discussion that any method of lowering the unit temperature will permit an increase in unit rating. For a given flow of air past the unit, as with natural draft, this was accomplished by increasing the size of the radiating fins. Likewise, for a given size of radiating fin, the same result can be attained by increasing the flow of air. Thus, if forced draft is used, temperature will be lowered and ratings may be increased. As it is possible to increase the flow of air enormously with a quite inexpensive fan, the size and cost of the rectifier for fairly large outputs can be reduced to a surprising extent from what would be needed with natural draft.

The unit design that would be best for fan cooling must derive the maximum benefit from the air passing the unit, must result in uniform distribution of the air so that all the units will be cooled equally and no hot-spots developed, and must proportion the unit ratings to the fan capacity so that the whole will be properly balanced. Careful laboratory study over a long period of time of different types of construction, sizes, and spacing of radiating fins at different measured volumes of air flow, resulted in the type of unit shown in Fig. 9. These units are mounted side by side and close together in a symmetrical arrangement, as shown in Fig.10, and when mounted in an air duct in proper relation to a suitable fan, constitute a fan-cooled rectifier.

The correct rating is again determined, as before, by comparing the losses at the rated output with the temperature rise curve of the units under forced draft. The result of this analysis is shown in Fig. 11 for the design used for operating motion picture arcs. The desired output is, for example, 65 amperes at 33 volts. This, reduced to a watt-per-disk basis, results in losses at various temperatures as shown in curve B. The unit shown in Fig. 9, with an air-flow of 60 cubic feet per minute, can dissipate losses with temperature rise as in curve A. The two curves cross nearly at right angles. It may be noted that the losses continue to decrease even up to 80°C., so that the design is quite stable.

A complete motion picture rectifier, then, consists of an assembly of units similar to Fig. 10, mounted so that the units are ventilated by suction from a fan, and the necessary transformers, relays, and terminal boards, all enclosed in a sheet-steel ventilated cabinet. Fig. 12 shows a typical completed assembly. Transformers are generally furnished with primary line voltage taps and secondary taps for close adjustment of the output voltage. Relays are included for protection of the rectifier unit to prevent operating unless the fan is energized. The entire unit weighs only 250 pounds and is 31 inches high, 20 inches wide, and 17 inches deep.

Usually one unit or its equivalent is needed for each arc. Since nearly always two arcs are to be operated, some economy results by mounting two sets of units in the same case, using the same transformer and fan, one set being connected to each arc. Care has to be taken with such a design to assure proper ventilation for all the units.

LIFE TESTS

When the rectifier was first put into commercial form, life tests were commenced so that we might know as quickly as possible what limitations existed in this direction. Now there are operating on test hundreds of units of various types

from 1 to 10 years old, all of which have given the same answer, namely, that the life of the rectifier when properly applied is indefinite. The performance with time of a Rectox used to operate a printing telegraph will serve as an example. In 3 years of continuous operation at full load, the output has dropped off only 7 per cent. Tests made on a standard 3-phase, elevator-controlled Rectox, so far covering 27,600 hours of operation, show similar results. The rectifier was connected directly to the a-c. line without intervening resistance, and no adjustment of voltage or load is ever made. In a $7^1/_2$-year test, or 65,000 hours, a number of 2-ampere, 6-volt battery chargers are still delivering rated output, with no indication of any limit to the life of the rectifier.

The use of Rectox rectifiers for operating motion picture arcs, then, is not a radically new departure, but merely another step in a process that has been going on for years, the application of the rectifier to industry. As in the past, each new application is carefully studied, and once all the facts are known, the rectifier has never failed to function as expected. Its usefulness as a tool in many other fields has long been known. Now we believe the same experience will be had in the motion picture field. In fact, it appears that rectification by copper-oxide has already been accepted by the industry as a highly satisfactory method of supplying the projection arc.

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APPLICATION OF THE COPPER-OXIDE RECTIFIER TO MOTION PICTURE PROJECTION*

C. E. HAMANN**

The application of the copper-oxide rectifier as a d-c. power supply for projection is by no means new. A fan-cooled type of copper-oxide rectifier was developed by the General Electric Co. in 1930, and applied successfully to the low-intensity type of lamp as well as the Hi-lo lamp.[1] With the advent of the Suprex type of arc an entirely new field has been opened up. The characteristics of the copper-oxide rectifier have been found to be admirably well adapted to the special voltage and current requirements of the Suprex arc and in this service it is rapidly supplanting other types of equipment.

Construction.—General constructional details of a typical commercial unit are illustrated in Fig. 1. The transformers and control panel are assembled as a

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* Presented at the Spring, 1936, Meeting at Chicago, Ill.

** General Electric Company, Bridgeport, Connecticut.

unit and located in the upper part of the casing. The copper-oxide stacks, together with the air baffles and the blower system, are also assembled as a single unit and installed in the lower part of the casing. Aside from these two unit assemblies, the only other parts are the control relays and protective switch.

Circuit Design.—It has been previously pointed out that single-phase rectification is not suitable for the Suprex arc due to the pronounced ripple in the d-c.

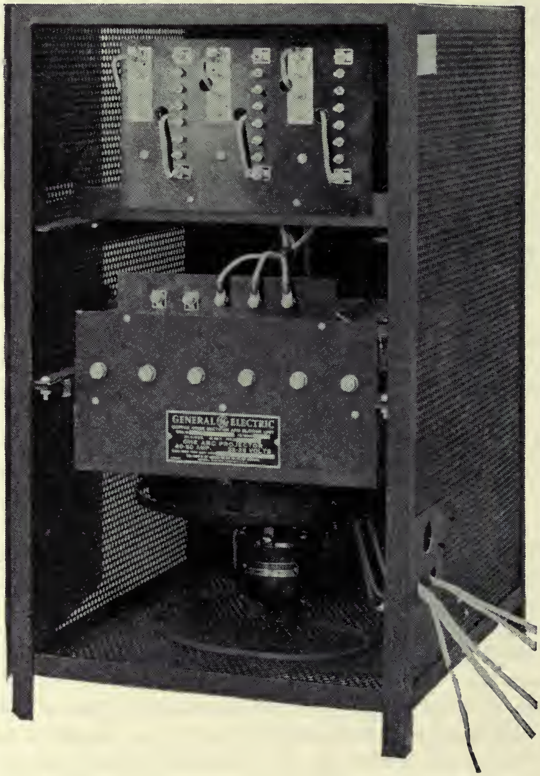

FIG. 1. Interior view of copper-oxide rectifier for projection service.

voltage output.[2] Hence, copper-oxide rectifiers for Suprex supply have been developed for polyphase service only. The rectifier circuit is designed for full-wave rectification of all three phases of the a-c. supply, and the resulting d-c. output has a ripple of relatively low magnitude and high frequency (360 peaks per second for 60-cycle, 3-phase).

The only noticeable effect of the d-c. ripple is a slight "sing" to the arc, which, it has been determined experimentally, can be eliminated by a small reactance

filter in the d-c. circuit. However, visual inspection supplemented by photometric tests indicate that the ripple is not of sufficient magnitude to cause any discernible effect in the light upon the screen. Therefore, the additional cost of a filter reactance does not appear warranted, and is omitted in the commercial design.

A typical circuit diagram of a 3-phase unit is illustrated in Fig. 2. The transformer connections are arranged delta-delta. Units for 2-phase service differ only in transformer design. A Scott-connected transformer changes 2-phase to 3-phase, so that the rectifier circuit and the output characteristics are identical to those of the 3-phase unit and therefore need not be discussed separately.

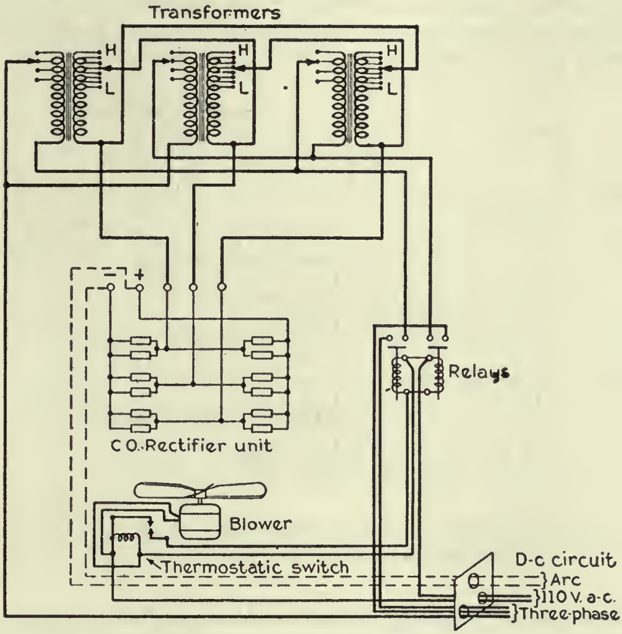

FIG. 2. Standard arrangement of internal wiring of 3-phase G. E. copper-oxide rectifier.

An examination of the wiring diagram will readily disclose the general scheme of the rectifier circuit, but a brief explanation of the control circuit may be in order. It will be noted that the blower motor and the relay holding coils are energized from a separate 110-volt single-phase circuit. The purpose is two-fold: (*a*) it provides a simple remote-control arrangement for starting and stopping the rectifiers; and (*b*) it permits operating the rectifier on two phases in the event of failure of any one of the phases of the 3-phase a-c. supply line.

Design Data.—In the design of a copper-oxide rectifier it is customary to base all calculations upon established data for the "unit bridge."[1] For a single-phase circuit a "unit bridge" consists of four disks or elements arranged in a full-wave

"bridge" circuit as shown in Fig. 3*a*. For a 3-phase circuit, with which this paper is chiefly concerned, the "unit bridge" consists of 6 disks arranged in a 3-phase full-wave "bridge" as shown in Fig. 3*b*.

Experience over many years has resulted in establishing certain standard limits of voltage, current, and temperature for the unit bridge. Thus, dividing the safe voltage limit of the unit bridge into the desired voltage rating indicates the number of disks that must be connected *in series* in each leg of the bridge circuit. Similarly, the current limit of the unit bridge divided into the desired current rating indicates the number of *parallel* groups of disks required in each leg of the bridge circuit.

The problem of design would be simple except that consideration must be given to the so-called "aging" characteristic of the copper-oxide element.[1] This can be defined as a gradual increase of resistance of the unit in the "forward" direction which tends to stabilize after 4000 to 5000 hours of use.

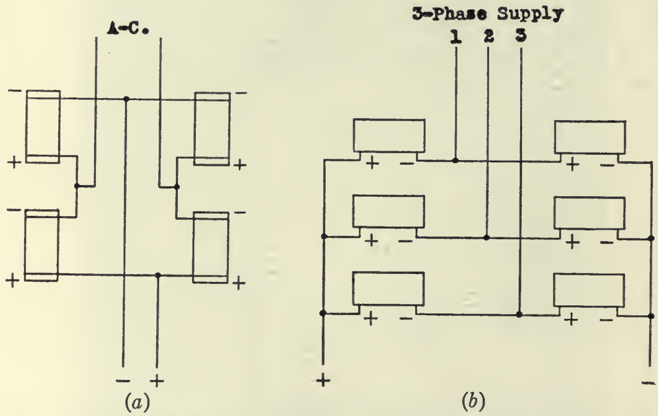

FIG. 3 (*a*) Arrangement of single-phase "unit bridge" circuit; (*b*) arrangement of 3-phase "unit bridge" circuit.

Aging is a function of temperature as well as of time, and the higher the operating temperature the greater will be the change of resistance before stabilization takes place. It is at once apparent that in order to maintain the initial output of a unit it will be necessary to increase somewhat the applied a-c. voltage after aging has taken place.

Care must be taken in the design to make sure that the final applied a-c. voltage necessary to maintain the rated output after aging will not exceed a safe value for the particular disk combination under consideration. Fortunately, sufficient data have been collected over a period of years to predict with reasonable accuracy the amount of aging that will take place for any given conditions of temperature.

In the commercial design, illustrated in Figs. 1 and 2, eight taps are provided on each transformer secondary winding, making it possible to adjust the applied a-c. voltage in steps of approximately 2 volts. This serves the dual purpose of

permitting a wide range of output adjustment and a ready means to compensate for aging.

In Fig. 4 is shown a family of curves giving the d-c. volt-ampere output regulation for each of the eight secondary taps on a standard 65-ampere unit. These curves illustrate the inherent regulation of this type of rectifier that makes it possible to operate without any form of external ballast in the arc circuit. It will be seen that the entire range of output, from 40 to 65 amperes, 30 to 35 volts, can be covered with the five lower taps, leaving three additional taps to compensate for aging, an amount that experience shows is more than ample.

Operating Efficiency.—The efficiency of a copper-oxide rectifier is regarded as the ratio of the d-c. watts' output to the a-c. watts' input. The losses in the rectifier consist of resistance losses in the forward direction through the copper-oxide elements, leakage in the "blocking" direction, and transformer losses. In the case

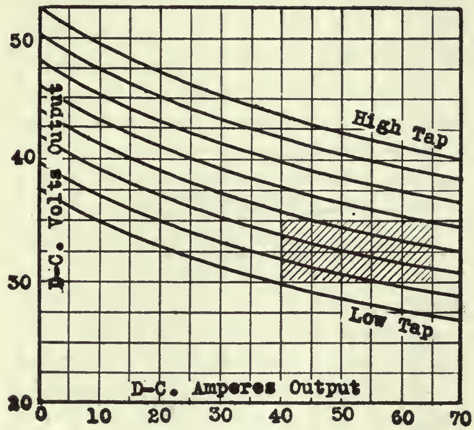

FIG. 4. Volt-ampere output characteristics of standard 65-ampere G. E. copper-oxide rectifier.

of the fan-cooled motion picture rectifier, the power consumed by the fan motor and the control relays should be added to the input to obtain the true over-all efficiency. Resistance losses in the copper-oxide elements represent the major part of the total losses. It has been previously shown that this resistance tends to increase with age up to a certain stabilizing point. It is at once obvious that aging tends to reduce somewhat the initial efficiency.

There is no rule-of-thumb method of stating the new and aged efficiencies of any rectifier, because the difference depends upon the ratio that the rectifier resistance bears to the total impedance of the rectifier-load circuit. If the rectifier resistance is a small part of the total impedance of the circuit, then a considerable change in rectifier resistance will mean only a slight change in the total impedance of the circuit, and consequently only a slight change in efficiency.

Aging being a function of temperature, an adequate system of forced ventilation will permit operating at a considerably higher current-density per unit

bridge than would be the case with the conventional air-cooled type of unit. Tests on fan-cooled units operating at various current densities continuously since 1929 have given the necessary data for establishing safe limits with respect to current density and temperature.

With a fan-cooling system capable of limiting the temperature rise of the copper-oxide elements to a maximum of 2 or 3 degrees C., a maximum current density of 2 amperes per unit bridge (3-phase) appears safe. It may be concluded that under these conditions it will not be necessary to apply an a-c. voltage in excess of 8 volts per unit bridge in order to maintain an output of 7 volts d-c. per unit bridge after aging has taken place.

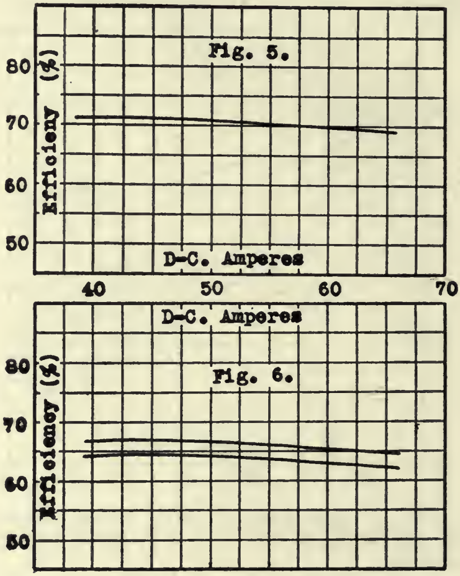

FIG. 5. Efficiency (new) of standard 65-ampere G. E. copper-oxide rectifier.
FIG. 6. Upper and lower limits of predicted efficiency of standard 65-ampere G. E. copper-oxide rectifier.

Fig. 5 shows the over-all operating efficiency of a standard 65-ampere unit (new), and includes the power consumed by the fan motor, relays, and protective switch. Fig. 6 shows the upper and lower limits of the predicted efficiency after aging has taken place.

It should be kept in mind that several thousands of hours of continuous use are required before the aging begins to approach stabilization, and this, measured in terms of theater service, is a matter of years.

Inspection of Fig. 5 indicates a somewhat higher efficiency at 40 amperes than at the full-load point of 65 amperes. By increasing the number of parallel groups,

and in this way reducing the current-density per unit bridge, it would be possible to make the point of maximum efficiency coincide with the full-load point on the curve, but the increase in size and cost of the unit would more than offset any possible advantage from the slight gain in efficiency.

On the other hand, any attempt by the designer to economize on materials by reducing the number of parallel groups and increasing the current-density per unit bridge will mean increasing the impressed voltage to a point in excess of the maximum safe limit of 8 volts per unit bridge, thus introducing a risk of possible breakdown by puncturing the oxide film.

Life.—It has been frequently stated that a copper-oxide rectifier properly applied will last indefinitely. Factory life-tests now running into the tenth year as well as hundreds of different industrial applications all tend to bear out this claim.

The percentage of troubles in the field has been gratifyingly small, and such troubles as have occurred are usually traceable either to misunderstanding the operation of the unit or to overloading due to inadequate wiring and equipment.

Conclusion.—There are at the present time upward of 600 G. E. motion picture type copper-oxide rectifiers in the field, which furnishes ample proof of the acceptance of this type of equipment by the industry. Good engineering and strict adherence to the design limits described above should result in a high degree of reliability, exceptionally long life, and freedom from trouble.

Aging, if given proper consideration when designing the rectifier, will result in only a small reduction in operating efficiency over a period of years. A careful check of a number of units in service for more than a year indicates that they are still maintaining their original output with no change in adjustment.

The Projection Practice Committee of the Society[2] early recognized the merits and advantages of the copper-oxide rectifier, and others who unhesitatingly predicted its success in the motion picture field are seeing their predictions well on the way toward fulfillment.[3,4,5,6]

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FALL, 1936, CONVENTION

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TECHNICAL SESSIONS

All technical sessions will be held at the Sagamore Hotel (Convention headquarters) except the session on Tuesday morning, which will be held in the auditorium of the Kodak Research Laboratories at Kodak Park.

HEADQUARTERS

The Headquarters of the Convention will be the Sagamore Hotel, where excellent accommodations are assured. A reception suite will be provided for the Ladies' Committee, which is now engaged in preparing an excellent program of entertainment for the ladies attending the Convention.

Special hotel rates guaranteed to SMPE delegates, European plan, will be as follows:

One person, room and bath	$ 3.50
Two persons, room and bath	6.00
Parlor suite and bath, for two	10.00
Parlor suite and bath, for three	12.00

Room reservation cards will be mailed to the membership of the Society in the near future and everyone who plans to attend the Convention should return his card to the Hotel promptly in order to be assured of satisfactory accommodations. Registrations will be made in the order in which the cards are received. When the Sagamore Hotel is booked to capacity, additional accommodations will be provided by the Hotel Arrangements Committee at another hotel in the immediate vicinity of the Sagamore.

A special rate of fifty cents a day has been arranged for SMPE delegates who motor to the Convention, at the Ramp Garage, near the Hotel.

Golfing privileges may be arranged for any of the Convention delegates by consulting the Chairman of the Local Arrangements Committee.

REGISTRATIONS

Registration Headquarters will be located on the Sagamore Roof. All members and guests are expected to register, as admittance to certain sessions may be contingent upon the display of a membership badge or special ticket. Admit-

tance cards will be issued at the registration desk for the special lecture on Monday evening and for the invitation luncheons on Tuesday and Wednesday noons at Kodak Park and the Bausch & Lomb Optical Company, respectively. Reservations for the Informal Luncheon on Monday and for the banquet on Wednesday should be made at the registration desk.

Identification cards will be honored at Loew's *Rochester* and the *Century* and *Palace* Theaters, the latter two through the courtesy of the Monroe Amusement Company.

SEMI-ANNUAL BANQUET

The Semi-Annual Banquet and Dance of the Society will be held at the Oak Hill Country Club on Wednesday, October 14th, at 7:30 P.M., at which time the Progress and Journal Awards will be made. Motor-coach transportation will be provided to and from the Club by the Transportation Committee.

ROCHESTER RESTAURANTS

In addition to the Main Dining Room and the Coffee Shop at the Sagamore Hotel, where excellent meals may be obtained, there are several leading restaurants in the downtown district, as follows:

Laube's Old Spain, 11 East Avenue
Odenbach's Restaurant, 14 South Avenue
Odenbach's Coffee Shop, Clinton and Main (Dinner Dancing)
1078 University Ave. A reasonably priced family restaurant.
Manhattan Restaurant, 25 East Avenue
Seneca Hotel, 26 Clinton Avenue S.

INVITATION LUNCHEONS AND INSPECTION TRIPS

The Eastman Kodak Company has invited all visiting members of the Society to a complimentary luncheon at Kodak Park on Tuesday, October 13th at 1:10 P.M. Inspection trips through the Kodak Park Works and the Kodak Research Laboratories will be arranged during the afternoon.

On Wednesday, the Bausch & Lomb Optical Company has invited all visiting members to a complimentary luncheon at their plant on St. Paul Street at 1:10 P.M. An inspection tour of the plant and the Scientific Bureau will be arranged following the luncheon. A special trip through the B & L glass plant will start at 8:30 A.M. (at the plant) Wednesday morning.

The details of several other trips, for which reservations should be made, are as follows:

Stromberg Carlson Telephone Manufacturing Co., 100 Carlson Road.—Two-hour trip, including engineering and acoustical research laboratories and manufacture and assembly of radio sets and telephone equipment.

Delco Appliance Corporation, 391 Lyell Ave.—Two-hour trip Tuesday and Wednesday afternoons. Trip includes examination of finished product display, visit to engineering laboratories, and tour of the plant departments housing interesting product operations. Registration for visit desired.

Gleason Works, 1000 University Avenue.—One-hour trip showing manufacture and assembly of gear machinery. Advance registration desired.

Taylor Instrument Co., 95 Ames St.—Two-hour trip showing manufacture of clinical and household thermometers, aneroid barometers, industrial temperature recorders and controllers, *etc.* Engineering and Research Laboratories and special display of instruments in operation. Advance registration desired.

Wards Natural Science Establishment, 302 N. Goodman St.—This firm specializes in supplying models for museums, schools, and colleges. Trips may be arranged at any time without previous registration.

It is assumed that delegates will arrange for their own transportation for all industrial trips with the exception of those to the Bausch & Lomb Optical Co. and the Kodak Park Works of the Eastman Kodak Co., for which motor-coach service will be provided on the dates specified.

PROGRAM

Monday, October 12th

9:00 a. m. *Sagamore Hotel Roof*
Registration
Society business

10:00 a. m.–12:00 m. Committee reports
Technical papers program

12:30 p. m. *Sagamore Hotel Main Dining Room*
Informal Get-Together Luncheon for members, their families, and guests. Brief addresses by several prominent members of the industry.

2:00 p. m.–5:00 p. m. *Sagamore Hotel Roof*
Technical papers program.

8:00 p. m. *Eastman Theater*
"Color Photography" (with demonstrations and motion pictures), Dr. C. E. K. Mees, *Vice-President in Charge of Research,* Eastman Kodak Co., Rochester, N. Y.

Tuesday, October 13th

9:00 a. m. Buses will be at the Sagamore Hotel to transport members and guests to the Kodak Research Laboratories at Kodak Park.

10:00 a. m.– 1:00 p. m. Technical papers program in the auditorium of the Kodak Research Laboratories.

1:10 p. m.	Invitation luncheon at Kodak Park Works of Eastman Kodak Co.
2:00 p. m.–5:00 p. m.	Inspection tour of Kodak Park and the Kodak Research Laboratories. The program for the evening of this day will be announced in a later issue of the JOURNAL.

Wednesday, October 14th

10:00 a. m.–12:30 m.	*Sagamore Hotel Roof* Technical papers program.
1:10 p. m.	Invitation luncheon at Bausch & Lomb Optical Co. Transportation to the Bausch & Lomb plant will be provided. Buses will leave the Sagamore at 12:30 P.M. sharp.
2:00 p. m.–5:00 p. m.	Inspection tour of the Bausch & Lomb plant.
7:30 p. m.	*Oak Hill Country Club* Semi-Annual Banquet and Dance of the S. M. P. E.: addresses and entertainment. Motor-coach transportation will be provided to and from the Club by the Transportation Committee. Coaches will leave the Hotel promptly at 7:00 P.M.

Thursday, October 15th

10:00 a. m.–12:00 p. m.	*Sagamore Hotel Roof* Technical papers program
2:00 p. m.	Technical papers program Society business Adjournment of Convention

APPARATUS EXHIBIT

There will be no general apparatus exhibit because of the limited display space at the Convention headquarters. The Papers Committee, however, is arranging to hold the usual Apparatus Symposium, and would like to be notified of anv papers for this session.

POINTS OF INTEREST

The University of Rochester.—The University occupies two sites, the original location between Prince and Goodman Streets on University Avenue, and the River Campus in the southwest section of the city. For nearly seventy years after its organization the University was operated as a Liberal Arts College, but in 1918 the School of Music was organized through the generosity of the late

George Eastman, and the school now bears his name. In 1921 it occupied modern buildings in the downtown section of the city, including the beautiful Eastman Theater. This theater is one of the chief cultural centers of the city, being the home of the Rochester Philharmonic Orchestra and the Civic Orchestra, and being the scene of many other musical and dramatic events.

In 1920 the School of Medicine and Dentistry was organized with a generous endowment provided largely by Mr. Eastman and the General Education Board.

The Bausch & Lomb Memorial Laboratory, housing the Department of Physics and the Institute of Optics, is located on the River Campus. This Institute was organized through the coöperation of Rochester optical industries, for the purpose of providing a center of teaching and research in the field of optics.

The total enrollment of all departments of the University exceeds 4000 students.

The Genesee River.—At the south edge of the city the river connects with the New York State Barge Canal. A barge channel is maintained to the center of the city at the Court Street dam. Below the dam the river enters a rocky bed and passes over five waterfalls having a total drop of 267 feet. These falls supply 50,000 horsepower to the city's industries. At the foot of the falls the river enters a deep gorge, through which it flows to its mouth on Lake Ontario, seven miles north of the business district. A drive north on St. Paul Street along the river to Veterans' Memorial Bridge which spans the gorge, and then across the bridge and north on Lake Avenue to the lake will be well worth while. Two city parks, Maplewood and Seneca, occupy opposite banks of the gorge near the Veterans' Bridge. Ontario Beach Park at the north end of Lake Avenue has a fine public bathing beach.

East Avenue.—This is one of the finest residential streets in this part of the country, extending from the downtown district east and south to Pittsford. At 900 East Avenue is located the former home of George Eastman, bequeathed by him to the University and now occupied by the President of the University of Rochester.

Colgate-Rochester Divinity School.—The campus is situated on a beautiful hill adjacent to Highland Park. It consists of a group of fine modern buildings grouped around the Divinity Tower, a dominating feature of the landscape. This school, organized in 1928 by the Baptist Education Society, combines and continues the activities of the Colgate Theological Seminary, formerly of Hamilton, N. Y., and the former Rochester Theological Seminary. About 100 students are enrolled.

Durand Eastman Park.—This beautiful park extends for two miles along the shores of Lake Ontario and extends back through rolling hills covered with trees and flowers of many varieties. There is a bathing beach and public golf course. The park is reached by driving north on Culver Road to the park entrance.

Genesee Valley Park.—Located along the river adjacent to the River Campus of the University. Contains a public golf course, playgrounds, and picnic sites.

Highland Park.—A few minutes drive from the River Campus (east on Elmwood

to Goodman, north to the park). Contains 3900 varieties of trees, shrubs, and perennials. Particularly noted for its display of lilacs, peonies, and azaleas.

Mendon Ponds Park.—A few miles southeast of the city, reached over routes *15* and *65*. The site of an old camping ground of the armies of the expedition against the Seneca Indians. Contains three ponds, bridle trails, and picnic grounds.

Powder Mill Park.—On the site of an old, carefully hidden powder mill. Contains a trout fish hatchery, and is a favorite picnic site. Located fifteen miles east of the city on route *15*.

Letchworth Park.—Located on the upper Genesee River about 50 miles south of Rochester. Contains some of the most notable waterfalls and river-gorge scenery in the eastern United States. Roads and foot-trails lead to three large falls, along the edge of deep rocky gorges and the deep wooded canyon below the falls. Picnic sites of unusual beauty abound, and there are cabins for the overnight visitor. Take routes *35–253–36–245*.

The Finger Lake Region.—This famous scenic region of lakes, hills, and waterfalls lies within an hour's drive to the south and east of Rochester, and offers dozens of motor trips through country of unusual beauty. There are six large lakes, the two largest of which, Seneca Lake and Cayuga Lake, are nearly forty miles in length. They are surrounded by wooded hills which rise to an altitude of 2300 feet. There are nine state parks covering an area of 5000 acres and containing 1000 waterfalls and many scenic gorges. Visitors driving from Rochester to Ithaca will pass through the heart of the region. Several routes may be chosen passing through points of particular interest. Information and road maps for this trip may be obtained at the registration desk, where there will also be available maps for those wishing to plan more extended trips.

Niagara Falls.—Ninety miles west of Rochester. May be reached over route *104*.

SOCIETY ANNOUNCEMENTS

FALL, 1936, CONVENTION AT ROCHESTER, OCTOBER 12TH-15TH, INCLUSIVE

Details concerning the approaching Convention at Rochester, beginning October 12th, will be found on page 353 of this issue of the JOURNAL, and at the foot of the inside front cover page.

NOMINATIONS FOR OFFICERS FOR 1937

About the time this issue of the JOURNAL is mailed to the membership of the Society, ballots will also be mailed for voting upon the nominees listed below for office for 1937. These nominations were completed at the meeting of the Board of Governors held at New York on July 10th:

President: S. K. Wolf
Executive Vice-President: H. G. Tasker
Editorial Vice-President: J. I. Crabtree
Convention Vice-President: W. C. Kunzmann
Secretary: J. Frank, Jr.
Treasurer: L. W. Davee
Governors: M. C. Batsel
J. C. Burnett
A. N. Goldsmith
J. L. Spence

Provision is made in the ballot also for voting for other than those named. Two of the four nominees for the office of Governor are to be elected.

SECTIONAL COMMITTEE

As representative of the Sectional Committee on Motion Pictures, ASA, Mr. S. K. Wolf, *Executive Vice-President* of the SMPE, has been appointed to attend the meeting of the International Standards Association at Budapest on September 3rd and 4th. Delegates from the nineteen national standardizing member-bodies of the ISA will attend the meeting, and it is hoped that an agreement will be reached in the matter of 16-mm. sound-film standardization, so that the difficulties resulting from the existence of the two standards, the SMPE and the DIN, may be overcome.

In addition, steps will be taken toward standardization in the 35-mm. field, which it is expected will not present any considerable difficulty.

ADMISSIONS COMMITTEE

At a recent meeting of the Admissions Committee, at the General Office of the Society, the following applicants for membership were admitted to the Associate grade:

ARGUELLES, E.
2 Poniente 510
Puebla, Pue., Mexico.

BAHLER, W. H.
Eastman Kodak Co.
Rochester, N. Y.

BAPTISTA, C. O.
308 S. Wabash
Chicago, Ill.

BARKER, H. G.
149 Fountain Road
Tooting, S. W. 17
London, England

BERG, A.
1835 Burnside Ave.
Los Angeles, Calif.

BOLTON, A. C. J.
1, Edward Road
Chadwell Heath Essex
London, England

BOOTH, F.
5, West Meade
Swinton Lanes, England

BOUZEMBERG, A.
c/o French Line
610 Fifth Ave.
New York, N. Y.

DARBY, A. W.
39, Levendale Road
Forest Hill
London, S. E. 23, England

FRANCK, E. W.
299 Pacific St.
Paterson, N. J.

HAMANN, C. E.
General Electric Co.
1285 Boston Ave.
Bridgeport, Conn.

HAYSLETT, L. E.
The Rudolph Wurlitzer Mfg. Co.
North Tonawanda, N. Y.

HOLLAND, G. E.
1935 Biltmore St. N.W.
Washington, D. C.

HORNER, F. W.
614 Upper Mt. Ave.
Upper Montclair, N. J.

HOVER, T. P.
410 Marian Ave.
Lima, Ohio

KNECHTEL, L.
George Humphries & Co.
71 Whitfield St.
London, W. 1, England

LENARD, A.
Pozsonyi ut 7.II.1
Budapest, Hungary

LEWIS, N. B.
c/o Kodak (Australasia) Pty., Ltd.
Abbotsford, N. 9, Victoria
Australia.

LO, T. Y.
Cinema Dept. of Army
Affairs Committee
Wuchang, China

POPE, J.
7402 Chappell Ave.
Chicago, Ill.

ROSSIRE, H. McC.
317 S. Sherbourne Dr.
Los Angeles, Calif.

RUTHERFORD, G.
30 Highcroft Road
Toronto, Canada

SHAREN, W. B.
P. O. Box 443
Wallaceburg, Ontario, Canada

SILSBEE, B. F.
Chevrolet Motor Co.
Union & Natural Bridges Aves.
St. Louis, Mo.

SLIVKA, F. X.
P. O. Box 1777
Plaza Station
St. Louis, Mo.

THOMPSON, R. H.
4245 Riverton Ave.
North Hollywood, Calif.

VETCH, A.
1433 Silver Lake Blvd.
Los Angeles, Calif.

WILLIAMS, R. H.
Embassy Theatre
Castlereagh St.
Sydney, N.S.W., Australia

In addition, the following applicants have recently been admitted by vote of the Board of Governors to the Active grade:

GRUNAU, A.
2511 W. Aubert Ave.
Chicago, Ill.

HILDEBRAND, J. G., JR.
857 Boylston St.
Boston, Mass.

SARGENT, R.
Automatic Film Laboratories, Ltd.
513–515 Dowling St.
Moore Park
Sydney, N.S.W., Australia

JOURNAL

OF THE SOCIETY OF

MOTION PICTURE ENGINEERS

Volume XXVII **OCTOBER, 1936** **Number 4**

CONTENTS

JOURNAL
OF THE SOCIETY OF
MOTION PICTURE ENGINEERS

SYLVAN HARRIS, EDITOR

Subscription to non-members, $8.00 per annum; to members, $5.00 per annum, included in their annual membership dues; single copies, $1.00. A discount on subscriptions or single copies of 15 per cent is allowed to accredited agencies. Order from the Society of Motion Picture Engineers, Inc., 20th and Northampton Sts., Easton, Pa., or Hotel Pennsylvania, New York, N. Y.

Published monthly at Easton, Pa., by the Society of Motion Picture Engineers.
Publication Office, 20th & Northampton Sts., Easton, Pa.
General and Editorial Office, Hotel Pennsylvania, New York, N. Y.
Entered as second class matter January 15, 1930, at the Post Office at Easton, Pa., under the Act of March 3, 1879.

See p. 466 for Technical Committees

THE PHOTOELECTRIC CELL AND ITS METHOD OF OPERATION*

M. F. JAMIESON, T. E. SHEA, AND P. H. PIERCE**

Summary.—*A simple description of the laws governing the release of electrons from photoelectric surfaces, their collection at anodes, and the creation of ions in photoelectric cell gases by the "ionization" process, and questions of spectral selectivity of various photoelectric surfaces, the influence of spectral characteristics of illumination, and the dynamic characteristics of vacuum and gas-filled cells.*

Of all the many types of vacuum tubes associated with the reproduction of sound-on-film motion pictures, the tubes that appear to be the simplest from an electrical point of view—and, off-hand, one would also say from the manufacturing point of view—are the photoelectric cells. However, the fundamental theory of operation of the cell presents some of the most perplexing problems of atomic physics, and its manufacturing success depends upon unbelievably delicate and accurate proportioning of materials and extremely closely controlled activation processes.

So, despite its apparent simplicity, questions often occur to the user of photocells that are difficult to answer unless the fundamental characteristics are fairly well understood. With these facts in mind it seems as if there were considerable justification for bringing together some of the fundamental information concerning photoelectricity, and that real benefit might result from an informal discussion of the problems that have arisen and have been met in developing and applying this important adjunct to the field of sound pictures. This, then, is the object of this paper.

THE PHYSICS OF PHOTOELECTRIC EMISSION FROM METALS

Consider the atomic theory of the composition of matter, which pictures all matter as made up of sub-microscopic planetary systems called atoms, held together by inter-atomic forces of attraction and forming physical materials as we know them. Further, consider the

* Presented at the Spring, 1936, Meeting at Chicago, Ill.

** Bell Telephone Laboratories, Inc., New York, N. Y.

atom divided into smaller particles carrying electrical charges, arranged in the fashion of miniature solar systems with a positively charged proton or nuclear particle at the center, around which negatively charged electrons rotate in regularly defined orbits.

In a gas the atoms are quite widely separated. In a conducting metal the spacing is so small that the outermost, or valence, electrons of any one atomic system find themselves almost as free to move into adjoining atomic systems as to remain in their original galaxies. This is the atomic theory of electrical conduction. Thus, an electrically conducting metal contains a great many electrons that drift freely from one atom to another and can be directed in their drift by an externally applied force.

It seems quite plausible that a "free," or valence, electron, when it is deep within the metal, experiences almost balanced forces of attraction, surrounded as it is upon every side by exactly similar atomic systems. As it approaches the surface of the metal, however, it encounters quite a different situation. Upon one side of the surface the closely packed atoms of the metal exert a stronger force of attraction for the electron than do the forces contributed by the more widely separated atoms of the outside atmosphere. Therefore, unless the electron has acquired some additional energy of motion, or kinetic energy, it will not be able to cross the boundary at the surface, but will stay within the metal.

This additional kinetic energy required to carry the electron across the surface boundary, since it is dependent upon the relative density or packing of the atoms, will vary as the relative density varies, and will thus be different for different metals and will be characteristic of the particular metal in question.

If a negatively charged particle is subjected to the influence of an electric field, it will be attracted toward the region of more positive or higher potential. Upon moving toward the higher potential it will gain energy of motion or kinetic energy. If a moving electron is projected into a field in the direction opposite that in which it would normally move if starting from rest, it will be slowed down or will lose kinetic energy. Whether work is done upon the field by the charged particle, or upon the charged particle by the field, the energy can be expressed in terms of the voltage or difference of potential through which the particle moves.

In a similar manner, an electron that has gained enough kinetic energy from the effect of light falling upon the metal to carry the

electron across the surface boundary, loses a part of its kinetic energy in crossing the boundary, and the loss of energy can be expressed by an equivalent voltage. As was mentioned in a previous paragraph, this energy loss depends upon the particular metal in question, and the equivalent voltage is known as the *work function* of the particular metal surface and is generally denoted by Φ. A list of work functions for various metals is given in Table I.

TABLE I

Work Functions and Photoelectric Thresholds of Various Metals

Metal	Work Function (Volts)	Photoelectric Threshold (Ångström Units)
Barium	1.76 to 2.29	7000 to 5400
Potassium	1.76 to 2.25	6700 to 5500
Rubidium	1.8 to 2.2	6800 to 5700
Caesium	1.9	6400
Sodium	1.9 to 2.46	6400 to 5000
Lithium	2.1 to 2.9	5800 to 4300
Strontium	2.3	6000
Calcium	2.7	4475
Zinc	3.32	3720
Copper	4.1 to 4.4	3000 to 2750
Tungsten	4.58	2700
Iron	4.7	2620
Silver	4.73	2610
Gold	4.82	2650
Nickel	5.01	2463
Platinum	6.3	1962

Several ways are known of supplying the additional kinetic energy to the free electrons of a metal to enable them to cross the surface boundary. One of the most familiar ways is to heat the metal and thus increase the thermal energy of the electrons and cause emission, as is done in the filament of a vacuum tube. The method in which we are most interested in this paper is that of imparting the additional energy by illuminating the metal surface.

Light radiation has been assumed to consist of discrete bundles of energy called *quanta*. Einstein's expression for the energy imparted to the electron is

$$\frac{1}{2}mv^2 = h\nu - \Phi$$

where $mv^2/2$ is the kinetic energy of a particle of mass m moving

with a velocity v; $h\nu$ is the quantum of energy, which depends in value upon the frequency ν of the radiator, and Φ is the work function of the surface.

This expression gives us the kinetic energy of a photoelectron after emission, and states that the kinetic energy of such an electron is equal to the energy of the light quantum less the energy lost by the electron in crossing the boundary of the surface.

An important consequence of this analytical expression is the fact that as ν, the frequency of the radiation, decreases, a point is reached where $h\nu - \Phi$ is exactly zero, which means that no kinetic energy is left after the electron crosses the boundary, so that it is held at the surface of the metal. Therefore, a threshold frequency must exist such that light of a higher frequency will cause photoemission, whereas light of a lower frequency will not. Such a threshold frequency has been experimentally found to exist exactly in accordance with the equation, and values of this threshold are given in Table I.

So far we have considered only pure metals in bulk. Thin films of metals deposited upon glass or other conducting metals; surfaces activated by the deposition of surface layers such as the hydride of the metal formed by passing an electrical discharge through hydrogen to the cathode; and an interesting group of surfaces formed by depositing a layer of dielectric material such as sulfur, or a layer of water vapor which reacts with the metal, or a treatment with an organic dye material; present theoretical problems of a very complex nature, but in many cases produce photosensitive surfaces many times more sensitive than bulk metals. Such a surface layer results in the motion of the threshold frequency toward the red end of the spectrum and a greatly enhanced response to visible light.

Still another type of surface, or possibly a modification of an already mentioned type, consists of a composite mixture of three or more components, such as a base or bulk metal, oxides of this bulk metal, a second metal and possibly its oxide, all intimately associated in a complex surface matrix.

Consistent with the above-described theory are the following laws, derived empirically:

(*1*) The number of electrons released per unit of time by a photoemissive surface bears a direct proportionality to the intensity of the incident light.

(*2*) The maximum energy of the released electrons is not dependent upon the intensity of the incident light but is directly proportional to the frequency of the light.

RELATIVE EMISSION FROM VARIOUS MATERIALS

Physics has classified light as a wave motion in the ether. As such it takes its place among the rest of electromagnetic radiations as part of an extensive spectrum which with the exception of only a very few narrow regions has been studied; from cosmic rays as short as 10^{-12} centimeter continuously up through radio waves as long as 22,000 meters. The part of this radiation spectrum that affects the eye, known as visible light, occupies a very narrow portion of the whole spectrum, as shown graphically in Fig. 1.

The spectroscope has given us a great deal of information regarding the synthesis of light, because it makes possible the resolution of light into its various frequency components. A spark between metal

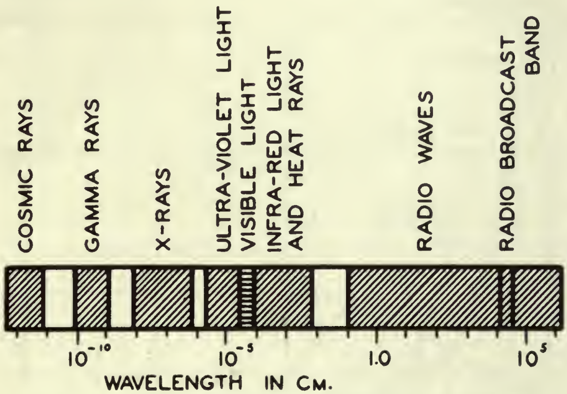


FIG. 1. The electromagnetic radiation spectrum.

electrodes becomes a series of sharply defined differently colored lines. Electrical discharges through gases at low pressure, such as we see in present-day neon signs, also exhibit characteristic bright-line spectra, as does also the flaming portion of an arc between two electrodes. An incandescent metal source, such as a heated filament or the heated portion of the electrodes of an arc, on the other hand, radiates a so-called continuous spectrum, a continuous band of color ranging from the deep red end through red, orange, yellow, green, blue, indigo, and violet. Glass will not transmit frequencies corresponding to radiation in the ultraviolet, so if photoelectric surfaces are enclosed in glass bulbs they will not respond to ultraviolet radiation. On the other end, toward the infrared, glass is somewhat better, extending up to about 11,500 or 12,000 Å, so that incandescent sources

or gaseous discharges even though enclosed in glass will radiate a considerable band of infrared radiation, and photoelectric cells that will respond in the infrared can be inclosed in glass and still be fairly effective.

The light-source used for a particular photoelectric application can therefore be chosen, knowing its spectral characteristics, provided the characteristics of the photoemissive surface are also known. Incandescent metals, although radiating continuous spectra, do not

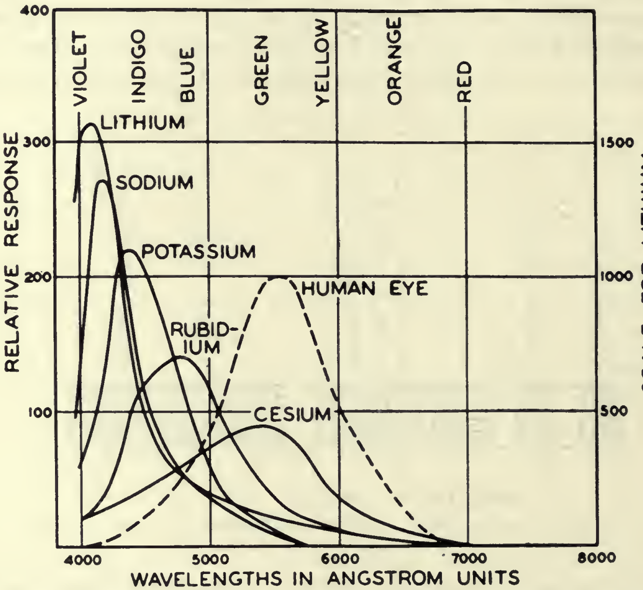
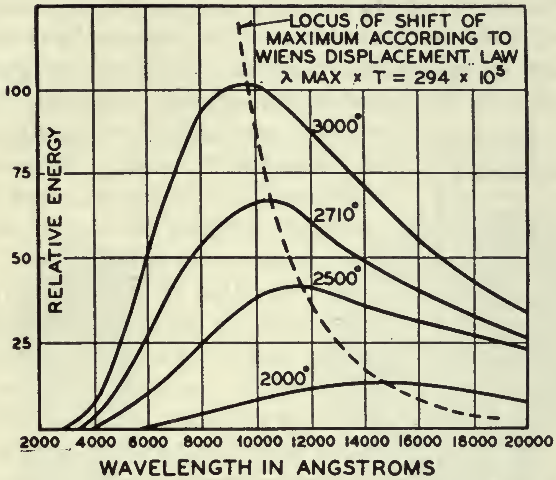


FIG. 2. Relative response of pure alkali metals to light of equal energy at various wavelengths.

radiate all frequencies equally strongly, as will be shown later in this section.

The source to be used thus depends upon the particular part of the spectrum desired. The basis of selection is the relative response to different parts of the spectrum exhibited by the particular photoemissive material to be used.

Photoelectric emitters do not respond with equal intensity to all wavelengths, but respond more readily and more strongly to radiation of particular wavelengths. Besides having, as we have seen, a characteristic cut-off or threshold wavelength beyond which the sur-



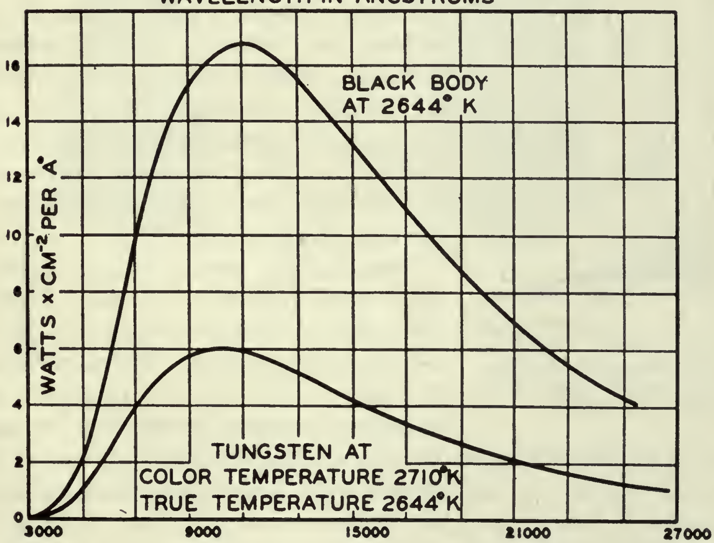


FIG. 3. (*Upper*) Spectral distribution of radiant energy from "black body" at various temperatures.

FIG. 4. (*Lower*) Comparison of spectral distribution of radiant energy from black body and from tungsten at same true temperature.

face is not photoactive, each particular surface has in general a different response characteristic. Curves of the color-sensitivity of the alkali metals that respond to visible radiation are shown in Fig. 2, where the ordinates represent the relative response to radiation of equal intensity throughout the spectrum and the abscissas represent the wavelengths of the radiation throughout the visible spectrum, with the approximate colors given below the wavelength scale. These curves, which are for mass metals, show relative response to *equal amounts of energy* at the various wavelengths.

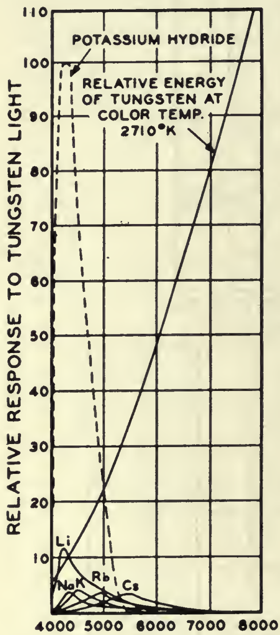


FIG. 5. Comparison of relative response of potassium hydride and alkali metals to tungsten light; color temperature, 2710°K.

The variation of intensity from continuous spectra due to incandescent metal sources can be accurately computed by the laws of radiation developed by statistical physics. An ideal radiator or "black-body" radiator is defined as a radiating material body capable of absorbing or radiating all frequencies. Radiation from such a black body varies in intensity depending upon its temperature, in accordance with definite laws. Typical radiation intensity curves for such a black body at various temperatures are shown in Fig. 3.

Incandescent metals depart slightly from ideal radiators or black bodies, since they do not in general absorb or radiate all frequencies. The distribution of energy from heated tungsten, for instance, compared to that for an ideal black body heated to the same true temperature is shown in the curves of Fig. 4. It will be seen from these curves that not only is the energy lower throughout the spectrum than that of the ideal radiator, but the position of the maximum-energy peak is shifted toward the short wavelength or blue end of the spectrum.

If the response curves of Fig. 2 were plotted, not to equal energy, but in terms of the response to the energy from a tungsten light-source operating at a known color-temperature, they will show which surfaces are most sensitive to light from a heated tungsten source.

This has been done in Fig. 5, along with the curve of the relative energy distribution of the source.

If, instead of the bulk metals, we have a composite surface such as potassium hydride, the reponse of the surface so formed when plotted in terms of the energy from a tungsten light is seen to be much greater than that of any of the bulk metals. The dotted curve of Fig. 5 is the response for such a potassium hydride surface. Potassium hydride was the material used in the first talking picture applications

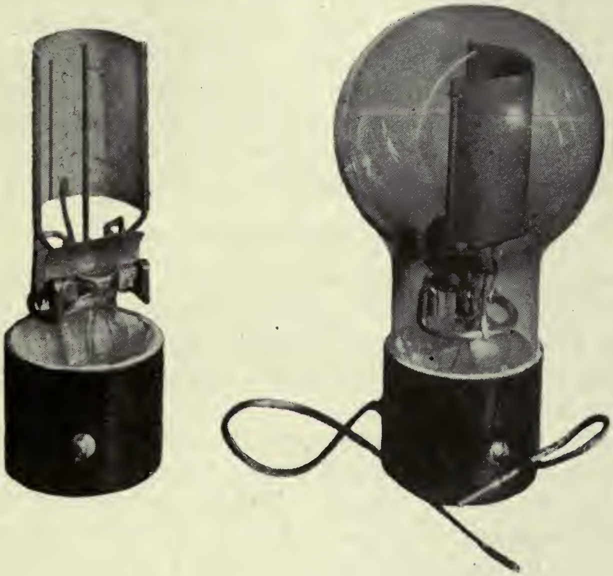


FIG. 6. *3-A* photoelectric cell.

because until very recently it was the most efficient emitter when used with a tungsten lamp as a light-source.

The relative sensitivities of photoelectric cells are usually expressed in terms of the number of microamperes of current that the cell will produce when one lumen of light falls upon the cathode. A lumen is a unit expressing quantity of light, and is defined as the quantity that falls upon one square-foot of surface from a point-source of one candle-power one foot from the surface.

Since the current that a cell produces is proportional to the number of lumens of illumination, it can be increased either (*1*) by increasing the size of the illuminated portion of the cathode, (*2*) by increasing

the horizontal candle-power of the light-source, or (*3*) by decreasing the effective distance of the cathode from the source. While increasing the intensity of light upon a small illuminated spot on the cathode theoretically increases the response, this method of increasing the response is open to the very real objection that the radiant energy may be increased to an intensity such as to overheat the particular small spot and drive some of the active material of the cathode away from that portion of the surface, and hence result in a diminution of the sensitivity of the spot. More uniform results will be attained by using as large an illuminated surface as the physical dimensions of the cathode will permit. Optical systems should therefore be designed to project, not a sharp image of light upon the cathode, but rather a larger more diffused image, over a considerable area of the active cathode. The number of lumens will be the same in either case, but local overheating will be avoided.

THE CS-O-AG PHOTOELECTRIC CELL

This type of composite photoelectric surface was first mentioned in literature by Koller in 1928, and has been developed in the Bell Telephone Laboratories for use in the *3-A* Western Electric photoelectric cell for talking motion picture applications. Its physical appearance is shown in Fig. 6.

Physically, the active elements of the cell consist of a semicylindrical cathode of thin sheet silver and a nickel anode rod located at the axis of the cathode cylinder. The concave surface of the cathode is the photosensitive surface and is turned toward the source of illumination. In the finished cell it presents a matte surface, which ranges in color for different cells from an iridescent bluish gray to a chocolate brown. The remaining mechanical elements of the cell compose the "chemical factory" for the production of the caesium during the activation of the cell.

The activation of the cell during manufacture consists in first "working up" the cathode surface, which is originally highly burnished 99.9 per cent fine silver, by alternately oxidizing and reducing the surface in a glow discharge in electrolytically generated oxygen, accomplished by first allowing the discharge to oxidize the silver by short glowing and then by holding the discharge long enough to heat up the thin silver sheet and decompose the silver oxide, which is relatively unstable at elevated temperatures. This process cleans the surface and produces a fine-grained matte texture. The cleaned

and roughened surface is then given a carefully calibrated oxidation, the amount of which is controlled by discharging a calibrated condenser through the oxygen. Each discharge deposits a known amount of oxide, the amount of which can be controlled by the number of times the condenser is discharged and by the pressure of the oxygen in the cell. Caesium is then generated by flashing a chemical pellet composed of caesium chromate and aluminum, contained in a thin molybdenum envelope forming a high-resistance link in a circuit that can be electrically coupled to a high-frequency coil external to the cell. The chemical constitution of the caesium pellet is such that once brought up to a certain elevated temperature, the chemical reaction supplies its own heat, similar to a thermite reaction, and the caesium that is formed is completely and quickly evolved as a heated vapor, which, because of its high vapor pressure, leaves the pill at once. The amount of caesium formed can be carefully controlled by accurately weighing the chemicals of which the pill is composed, and because of the high temperature of the reaction, all of it is shot out into the bulb as a heated vapor. This hot caesium is hot enough to elevate the temperature of the silver cathode should it strike it directly. Because of the unstable nature of silver oxide, some of it would break down into oxygen and metallic silver should such heating result. The vapor is, however, deflected by a suitably shaped deflecting shield between the pill assembly and the cathode, and strikes the cool bulb at a point opposite the concave surface of the cathode, where it condenses and deposits. This heat shield also protects the silver cathode from direct radiation from the heated molybdenum pill envelope, which reaches incandescence from the vigorous chemical reaction of the pill.

From the bulb surface, the condensed caesium is driven over to the silver oxide cathode surface by gently heating the bulb in a stream of hot air. The conventional radiation type of electric oven can not be used for this process, because by radiation from the hot oven winding it would heat the cathode more than it would the thin caesium film on the bulb, and hence decompose part of the carefully calibrated oxide surface before the caesium could be driven over to it where it could react. After the caesium is all on the cathode surface, the cell is heated still further, the caesium combines with the silver oxide, and a stable composite surface results, which is a colloidal mixture of caesium, caesium oxide, silver oxide, and finely divided silver reduced from the silver oxide. All the processes are carefully controlled,

even to the time and temperature of the heating in the hot air stream, and the finished product is capable of very great uniformity despite its critical composition.

When the process is correctly carried out, the resulting photosensitive surface possesses a work function that measures less than a volt; a relative response to equal energy, shown for a typical *3-A* type of cell in Fig. 7, with a peak of maximum response in the infrared region at about 8000 Å; and a microampere sensitivity of between 40 and 60 microamperes per lumen when a light-source of tungsten at a color temperature of 2710°K. is used.

A glance at the relative energy curve for tungsten at this temperature, Fig. 4, shows the energy maximum at about 10,500 Å, and shows why this type of surface is so effective for use with a tungsten light-source such as is used in the sound picture exciter lamp: namely, because its region of greatest response lies in the region of greatest energy from the tungsten light.

Fig. 7 shows the relative response of the *Cs-O-Ag* type of photoelectric cell compared with the potassium hydride cell, such as was used in the Western Electric *1-A* and *2-A* photoelectric cells, in terms of equal energy to indicate the actual positions of the spectral maxima. Fig. 8 shows the same data in terms of the energy from a tungsten filament light-source at a color temperature of 2710°K. The superiority of the *Cs-O-Ag* surface such as is used in the Western Electric *3-A* cell is at once apparent.

GAS-FILLED PHOTOELECTRIC CELLS

Even using the higher sensitivity of the *Cs-O-Ag* surface, the current that can be drawn from a photoelectric cell at reasonable values of illumination and with reasonable areas of illuminated cathode, is still of the order of only a few microamperes. It is possible to increase this feeble current several-fold by filling the cell with some inert gas at a low pressure, which by ionization will provide additional carriers of electricity. The kind of gas and the quantity of it are subject to critical limitations which should be understood by the user as well as the maker of photocells.

Consider, then, an electron driven from the photoelectric surface by the additional energy imparted to it by a quantum of light. As the electron emerges from the surface of the metal cathode of the photoelectric cell, it possesses a certain amount of kinetic energy. This is supplemented by the energy that it gains from the action of the

electric field between cathode and anode due to the external battery in the circuit. If the total energy of motion, or kinetic energy, reaches a certain definite value before the moving electron collides with a gas atom or molecule, the electron may collide with sufficient impact to knock out one of the electrons composing the atom.

The net result of a collision between a photoelectron and a gas atom may be the presence of the electron that has been knocked loose from the atom; the original electron that did the knocking out, and was thereby deflected into a new path; and the atom that is now short one electron, and is thus carrying a charge that is effectively positive by the amount of the negative charge of the electron it has lost. Three electrically charged particles therefore exist and can be influenced by the potential field established by a battery connected between cathode and anode; and if they reach the respective electrodes to which they are attracted because of their charges, they will result in a current three times as great as the current that would have resulted had the emerging electron gone directly from the cathode to the anode without colliding.

The process of breaking loose one or more of the electrons from an atom is known as "ionization." The voltage denoting the energy necessary to tear loose an electron is known as the "ionizing potential" of the atom of the gas and, of course, may possess more than one value. That is, a certain voltage may represent the energy necessary to free one electron, another value may be that required to free two electrons, and so on.

Three additional influences enter, which is the reason why it has been said that the resultant current "may" be three times as great. For example, in moving toward the cathode an atom with one or more electrons released by collision will encounter another electron—either one freed from some other atom, or one of the electrons from the photoemissive surface which does not itself possess enough energy to tear free any more electrons; and since the ionized atom is effectively positively charged, it will possess an attractive force that may cause the electron that it has encountered to attach itself to the ion, electrically neutralizing it so that even though it may move as far as the cathode, it will no longer carry a charge and no additional current will result. This effect is known as "recombination." Another alternative may present itself if the ion, carrying its effective positive charge, is accelerated sufficiently by falling through the potential field so that it, too, acquires an energy equivalent to the ionization

potential of the gas, and so that if it collides with another neutral gas atom it may do exactly the same thing that an electron with this energy does—namely, ionize the atom with which it collides, forming new free electrons and other ions. Still a third alternative exists, due to the fact that ionized atoms may be accelerated sufficiently before striking the cathode so that they possess enough energy actually to drive electrons from the metal of the cathode. The electrons so driven out are known as "secondary" electrons, and the emission resulting as "secondary emission."

All four of these effects are present in different degrees in a gas-filled photoelectric cell with a battery in the circuit—(*1*) ionization by the photoelectrons, (*2*) ionization by the accelerated ions themselves, (*3*) secondary emission from the ions striking the cathode, and (*4*) the opposing effect of recombination which in part neutralizes the effect of the other three processes. The resulting current in the external circuit is a complicated function of all four.

Fig. 9 shows the current that results when a photoelectric cell is illuminated with a constant illumination and the voltage is varied across the electrodes. If the cell is a vacuum cell, the curve with the long flat portion results; that is, a voltage is reached (about twenty volts) at which all the photoelectrons emitted are made to travel across to the anode; and beyond that voltage the current can increase only very slightly because no more electrons are available. If gas is admitted into the cell, a different condition takes place. When the voltage reaches the point at which some of the electrons can acquire an energy equivalent to 15.7 volts, the argon—which is the gas used in this case—is ionized by colliding photoelectrons and the current is no longer due only to photoemission. As the voltage is increased, more and more of the photoelectrons, and finally the ions themselves, produce additional ions and electrons, and the increase in current becomes greater and greater. If electrons or ions can acquire an energy of 47 volts, each may doubly ionize other gas atoms—that is, knock out two electrons; and because of the low work function of the photoelectric surface itself, each ion that collides with it may possess enough energy to knock out, not one, but many electrons from the metal. A point is finally reached at which the ionization process becomes cumulative, and the photoelectrons are no longer necessary for carrying on the ionization, which so far exceeds recombination that the discharge becomes self-sustaining and continues after the illumination is cut off. This condition is known as

the "spark" condition, and the current in such a discharge will build up to a value limited only by the resistance of the battery and connecting leads, or by the value of an external protective resistance in the circuit. Such protection is quite necessary, since the violent

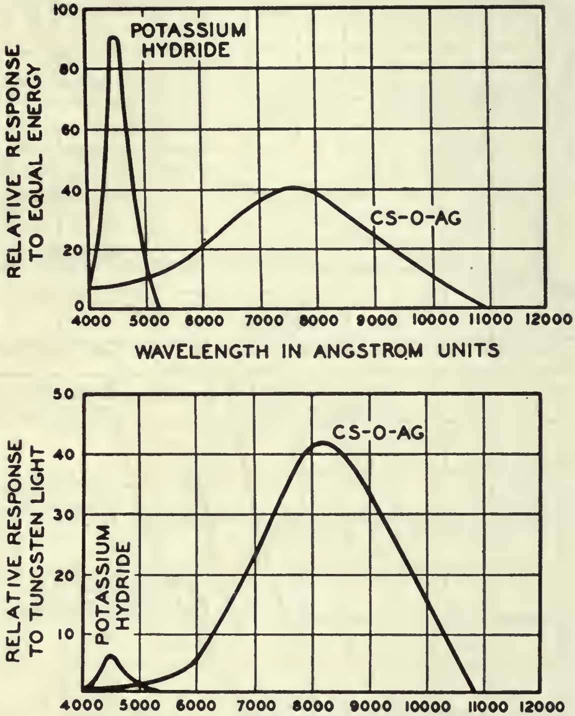
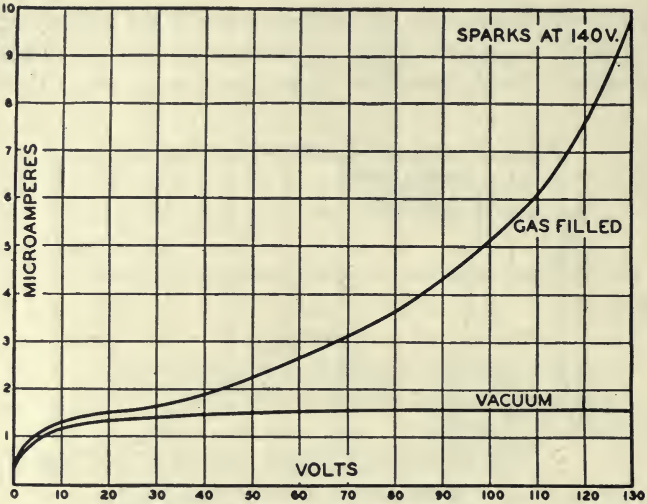


FIG. 7. (*Upper*) Relative spectral response of potassium hydride and *Cs-O-AG* photocells to equal energy.
FIG. 8. (*Lower*) Relative response of potassium hydride and *Cs-O-AG* photocells to tungsten light at color-temperature of 2710°K.

electrical spark or arc than can result at a high voltage would rapidly overheat the cathode and disintegrate the active surface.

The point at which the self-sustaining discharge takes place, of course, depends upon the density of the gas in the cell; the density of the photoemission which starts it, *i. e.*, the surface activity of the cell; or the intensity of the illumination; and to a lesser degree, upon the temperature of the cell. Also it depends upon the geometry



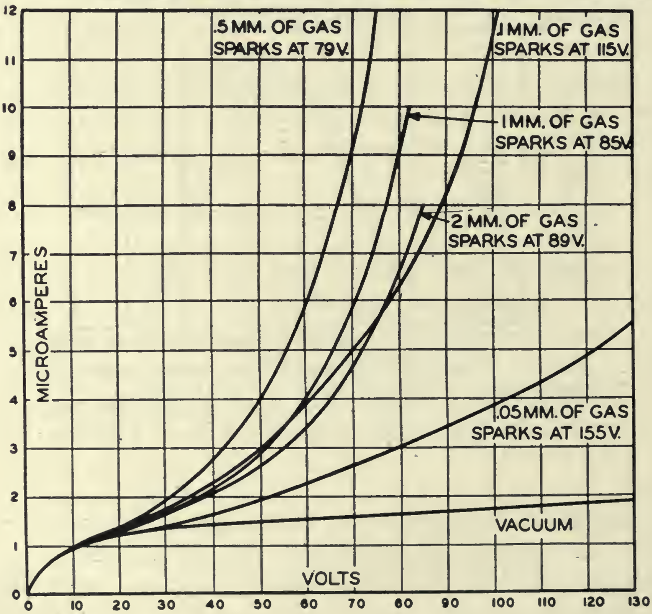


FIG. 9. (*Upper*) Current-voltage characteristics of argon-filled and vacuum *Cs-O-AG* cell of about the same surface sensitivity; 0.05 lumen on $^3/_4$-inch circular window.

FIG. 10. (*Lower*) Effect of gas pressure upon voltage-current characteristics of *Cs-O-AG* photoelectric cell at 0.05 lumen.

of the elements of the cell, and upon the disposition and shape of the electrodes, *etc.*

If the illumination of the photoelectric cell is interrupted, an interrupted output current will result. This is the basis for use of the cell in the reproduction of sound in talking motion picture applications. The varying density of the film sound-track is used to vary the

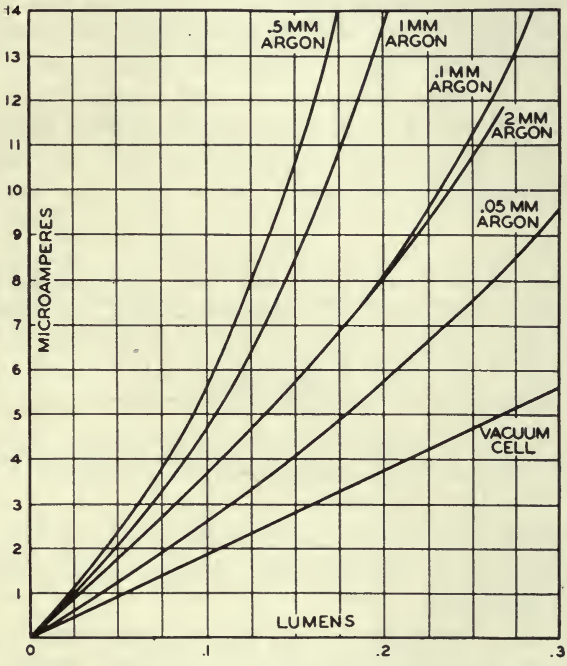


FIG. 11. Response *vs.* illumination at various gas pressures, at 60 volts.

illumination of the cell; and the magnitude of the current, which varies as a result of the change in illumination, can be amplified to produce a sound in a loud speaker. If faithful reproduction of the variation of intensity of the illumination passing through the film is desired, it is important, first, that the current through the photoelectric cell be linearly proportional to the illumination striking the cathode; that is, that the current will double when the illumination is doubled, or will halve when the illumination is halved. Experiment has determined, and empirical laws already stated show, that

the vacuum photocell possesses such a characteristic; but due to complexities in the ionization effects, the linear proportionality does not hold for gas-filled cells operated at higher voltages or high illuminations. The departure from linearity becomes greater, the higher the gas pressure in the cell—up to a certain point, as gas ionization plays a greater and greater part in the resulting current. Fig. 10 shows a family of voltage-current characteristics taken by varying the gas pressure in a cell fastened to the pumps so that the cell can be filled and pumped out, and the same surface conditions obtained for any gas pressure. Fig. 11 shows a similar family of curves for the same cell when the voltage is held constant and the illumination intensity varied. The vacuum cell shows a linear response —that is, even increments of illumination result in even increases in current. Gas-filled cells depart from this linear condition, the

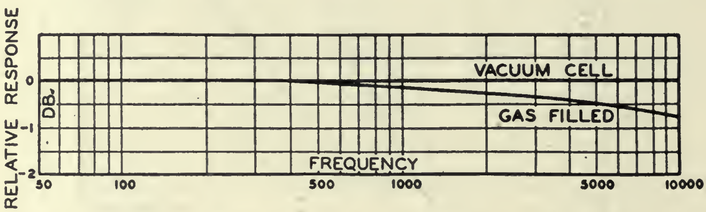


FIG. 12. Effect of gas in a *Cs-O-AG* photoelectric cell in terms of response to frequency of modulation of the light.

departure increasing with the pressure and passing through the same sort of maximum at 0.5-mm. argon pressure as did the voltage-current characteristics.

Another effect enters due to the fact that the times required by electrons and ions to travel across the inter-electrode space depend upon the relative sizes of the particles. Electrons, being small, travel at higher velocities than do the ions, since for the same amount of energy their velocities are inversely proportional to their masses. The result is that as the light is interrupted or varied at higher and higher frequencies, the electrons still travel across well within the times of the variations, but the heavier and slower moving ions can not follow as well. If the cell is placed in a standard amplifier circuit and the magnitude of the response to light of different frequencies is measured, the result will give us a characteristic such as shown in the typical experimental set of curves of Fig. 12. The gas-filled cell lessens in response at the higher frequencies, the extent depending

again upon the pressure of gas in the cell. The cell of Fig. 12 was one that had a relatively low pressure of argon, and the decrease in the response is less than that often encountered in cells containing higher pressures of argon. A decrease in response of only 0.7 db. at 10,000 cps. is easily compensated for in the amplifier circuit. Higher pressures of argon, and consequently greater variation in response, may produce distortion that is less easily compensated for. A vacuum cell will not show this decrease until very high frequencies are attained. The normal circuit application is such that these higher frequencies can not be utilized anyhow, and are unimportant commercially.

The lack of linearity of response *vs*. illumination, and this decrease in response with increase in frequency, give us two arguments for low gas pressures in the cell. Another important consideration intimately connected with the gas pressure in the cell concerns the voltage at which the cell sparks over.

Arbitrarily, a voltage across the cell equal, roughly, to 75 per cent of the voltage at which the cell sparks over is chosen. Such a value brings the operation well below the unstable region of the characteristic, and allows reproducible and stable operation of the cell.

Cells that show high values of response when tested in a test-set illuminating a large window area may, when subjected to an intense small-area illumination, show marked distortion characteristics due to being operated too closely to the spark potential of the cell.

Cells operated with a greater part of the cathode illuminated can be operated under higher gas pressures than can cells in which a small intense spot of illumination is used. Thus, the conditions under which the cell is to operate will govern to a considerable extent the pressure to which the cell can be filled.

Suffice it to say that careful selection of the argon pressure is of vital importance for sound picture applications in which lack of distortion is important. Microamperes per lumen do not tell the whole story, and cells that give high response when measured either in a conventional sound picture amplifier or in a photometer set-up are not necessarily the most suitable for high-quality reproduction. Often cells that are sold to replace standard equipment spark only a few volts above the standard operating voltage, and will operate almost in the glow-discharge region, in which they are unstable. Low surface activities are often bolstered up to values as high as or higher than those found in good photoelectric cells, so that the cells

appear very good when tested; but the gas pressures necessary so to bolster up the response introduce difficulties in operation that are difficult to locate. Resistances in the amplifier input circuits may effectively so limit the current from the cell that no visible glow discharge is observed; but unstable operation can result without any visible glow being present. The importance of cells designed to operate properly can not be overemphasized.

DISCUSSION

MR. TASKER: Does 0.05 argon pressure represent modern commercial practice?

MR. PIERCE: Yes. In the *3-A* Western Electric photoelectric cell that is normally used, the pressure is about 0.04 mm.

MR. KELLOG: I believe that the energy distribution curves showing the sensitivities of the several materials at various wavelengths were plotted on the basis of the energy radiated per unit difference in wavelength. It seems to me quite as logical, although perhaps not conventional, to plot the energy given off (or, if not the energy, then the current) per unit of difference in frequency instead of per unit difference in wavelength. It would also be possible to plot as ordinates the current per unit of difference in log frequency, or difference in log wavelength. This would be an intermediate type of curve. Each of the three ways of plotting the characteristic would make the maximum, or peak, occur at a different frequency. Of course, such curves are interconvertible, and so long as the scales are properly defined this should not lead to any confusion or misunderstanding; but the usual methods of plotting give decidedly different impressions. I was wondering whether there was any justification for one type over another.

MR. SHEA: I think the only justification is what is useful in interpreting them.

MR. CARLSON: Were the sensitivity curves shown for the different types of cells with tungsten filaments at various temperatures based upon the distribution of radiant energy from such sources as actually measured when enclosed in a glass envelope; or were they based upon the radiation as computed by Planck's formula?

MR. PIERCE: They were based upon measurements of tubes enclosed in glass envelopes.

MR. TASKER: The characteristic of all the gas-filled cells which, as Mr. Pierce says, gives rise to distortion, is, I suppose, somewhat controllable. The curve for distortion *vs.* coupling resistance between the cell and the succeeding parts of the circuit, for example, normally shows that the distortion is much higher for high coupling resistances than it is for low ones. I wonder whether that is merely a compensation that arises due to the fact that the applied potential passes through the same resistor referred to, so that as the current builds up, the potential applied to the cell becomes less; or would that give us an opposite effect? Why is it that there is less distortion with a lower coupling resistor?

MR. PIERCE: There should be no distortion with a vacuum photoelectric cell caused by the drop in potential in the resistance used to supply the potential

to the cell as well as to couple it to the amplifier tube. The current is practically independent of voltage, and is only a function of the illumination. In a gas cell, however, there may be distortion, caused by this potential drop, although not necessarily. In the gas cell the current-illumination curve for a fixed potential bends upward slightly with increasing illumination, and the current-voltage curve also bends upward with increasing voltage, so that the potential drop in the coupling resistance tends to compensate for the upward curvature of the current-illumination characteristic. A particular value of coupling resistance may give a straight-line dynamic characteristic with minimum distortion.

In cells that are operated too near the flashing potential the current-voltage characteristic bends upward rapidly with increasing voltage, so that the slight curvature in the current-illumination characteristic is very much overcompensated by the drop of potential in the coupling resistance, thus giving a curvilinear dynamic characteristic with corresponding distortion. Under these conditions the higher the coupling resistance the greater the potential drop, and hence the greater the distortion.

MR. CRABTREE: What happened when the tube began to glow at the critical voltage? Is the tube useless thereafter?

MR. PIERCE: If the glow persists it would heat up the surface so that it would probably lose its activity. If it is allowed to persist for only a few minutes it does not affect it.

RECENT ADVANCES IN THE ACOUSTICAL DESIGN OF MOTION PICTURE THEATERS*

S. K. WOLF AND C. C. POTWIN**

Summary.—*The various factors that must be considered in the acoustical design and treatment of theaters are outlined, as a guide to architects and engineers in solving the more common problems arising in this particular phase of motion picture engineering.*

Fundamental considerations, such as proportions, shape, sound insulation, stage, etc., are briefly covered. The relation of "fixed" absorption to surface acoustic treatment is also discussed. Curves recommended by Electrical Research Products, Inc., showing optimal and percentage optimal reverberation times as functions of volume and frequency, respectively, are offered. Particular stress is placed upon the necessity of carefully selecting the materials for theater treatment with respect to their sound-absorbing efficiencies throughout the frequency range.

Prior to the practical adaptation of sound recording and reproducing systems to the motion picture industry, the architect was concerned chiefly with decorative treatment in theater design. Little consideration, if any, was given to general acoustic requirements. The legitimate theater placed certain limitations upon design, although, in most cases, acoustics were left to chance, in the anticipation that the direct vocal and musical presentation would approach at least an acceptable standard of naturalness and intelligibility throughout the seating area.

The era of classifying the talking picture as a novelty has long since passed. The public is now more conscious of the quality and naturalness of the sound accompanying the picture, and their expectations in this respect are worthy of careful consideration in the technical field. How disappointing to an architect must be a patron's passing comment, "A beautiful theater; but the sound!" Such is frequently the case, however, even with the recent advances in theater acoustics. Architects and engineers must realize that good acoustic conditions are equally important to architectual and decorative treatment in theater design. The purpose of this paper is to outline briefly

* Presented at the Fall, 1934, Meeting at New York.

** Electrical Research Products, Inc., New York, N. Y.

the fundamentals that must be considered in the present as well as in future acoustical design and treatment of theaters.

DESIGN

(*1*) *Proportion and Shape.*—The area and relative dimensions of the lot upon which the theater is to be built are generally the limiting factors in this respect. The ideal proportions for the auditorium proper, and the ones that, as indicated by past experience, assure the most favorable distribution of sound energy, are of the order of 2:3:5 for the height, width, and length, respectively. This ratio is applicable to theaters having cubical contents ranging to approximately 500,000 cubic feet. Above this volume, the height would, for practical purposes, be less in its relation to the width and length.

The square type of theater is acceptable but not fully practicable, from the standpoint of proper distribution and illusion for all sections of the seating area. The long and narrow type, sometimes called the "shooting gallery," should, when possible, be avoided. Difficulties arising from multiple sound reflections and inadequacy of distribution are always present in this type.

The importance of avoiding pronounced and unbroken curved surfaces such as domes, rear walls, and vaulted ceilings, particularly when the centers of curvature fall within the limits of the theater proper, can not be too strongly emphasized. Reflections of sound energy from such surfaces generally produce echos and areas of either excessive or deficient loudness. Only with the proper use of efficient sound-absorbing materials may such surfaces be incorporated in the design, although to eliminate them is far more practical. In cases where the intricacy of architecture requires the use of curved surfaces even to a moderate degree, a competent acoustic consultant should be retained to suggest such modifications in design as may be necessary to avoid possible defects.

Non-parallelism of surfaces is an important consideration, particularly in the design of small theaters. Side walls should preferably be angled slightly, so as to reduce cross-reflections or standing-wave patterns between these surfaces. Where balconies are not provided, the contour of the rear wall surface should be well broken. A ceiling "stepped" slightly in uniform flat planes from the proscenium opening to the rear wall is also desirable, particularly in small theater design.

(*2*) *Stage.*—The correct design and treatment of the stage are

acoustic problems in themselves, and should be considered as carefully as the acoustics of the auditorium proper. In addition to allowing ample distance between the screen and the first row of seats for good vision, suitable space must be provided between the rear of the screen and the stage rear wall for accommodation of horns, baffles, and other necessary equipment. In the theater used exclusively for motion pictures, the distance should preferably be not less than 6 feet, which allows ample space for suspending, tilting, and flaring the horns.

The stage rear wall surface, in line with, and over an area at least approximating that of the screen, should preferably be of angular or staggered construction, to minimize the interference patterns frequently encountered when entirely flat surfaces are provided at this point. In theaters in which the distance between the screen and the stage rear wall is to exceed 10 feet, it is also frequently desirable to provide a drop of heavy weight-lined velour suspended behind the horns, of an area at least approximating that of the screen. The drop may be hung on lines, to be raised or drawn back, if necessary, to clear the stage for special presentations. It is generally desirable to indicate upon the drawings the requirements for the drop, although its ideal spacing behind the horns is best determined by a sound engineer when installing the horns and other equipment upon the stage. Suitable draping in the area between the side and top edges of the screen and the rear wall is also beneficial, particularly on large stages. The stage floor should in all cases be of heavy construction and well braced to prevent any possible resonance or vibration.

(3) *Construction.*—In densely populated areas and in locations where the theater would be subject to a high external noise level, care should be taken in design to avoid any masking effect produced by such interference. External noise may enter the theater *via* several channels: namely, the lobby, windows, and exit doors, if opened or of light construction, and through sound transmission caused by general vibration in the theater structure. The lobby should be separated as much as possible from the theater proper. All sections of the theater subject to external noise or vibration should be of heavy construction to minimize transmission through the building structure.

The projection room should be sound-proof, as far as practicable, and the inner wall and ceiling surfaces of this unit treated with an efficient sound-absorbing material.

ARTICULATION AND INTELLIGIBILITY

(*1*) *Reverberation Analysis.*—Having carefully considered the various phases of design affecting the acoustic condition, we must next determine, with all possible accuracy, the requirements of interior

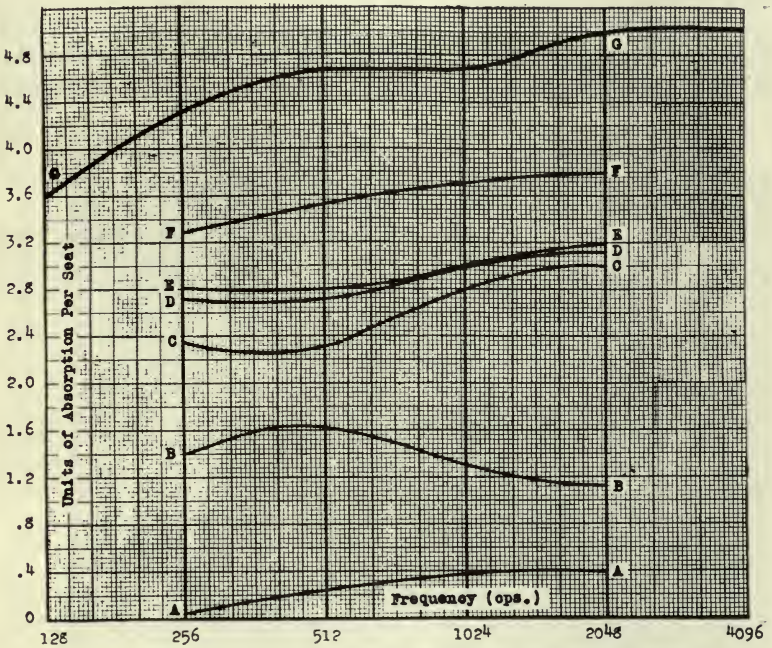


FIG. 1. Absorption characteristics of theater seats and audience.

Curve	Back	Seat
A	Wood	Wood
B	Panel Leather	Leather; Box Springs
C	Panel Velour	Velour; Box Springs
D	Full Velour	Velour; Box Springs
E	Full Mohair	Mohair; Box Springs
F	Full Mohair, on Springs	Mohair; Box Springs
G	Average Absorption of Individual	

surface absorption for correctly reducing the reverberation, interfering reflections, and echo. Several theoretical formulas have been derived for computing reverberation time, as determined by the absorption present in the theater, of which the most commonly used is the one developed by W. C. Sabine.[1] Formulas more recently developed are those of C. F. Eyring,[2] and W. J. Sette.[3] A correction

factor developed by V. O. Knudsen[4] takes into consideration air absorption as a function of the enclosed volume and humidity. These latter formulas have increased the accuracy of computation over that of the original Sabine formula, and their use is preferred from this standpoint.

It is commonly known that the absorption present in a theater is a function of the type of seats, the percentage of seats occupied by the audience, and the quantity of carpets, drapes, and other absorbing

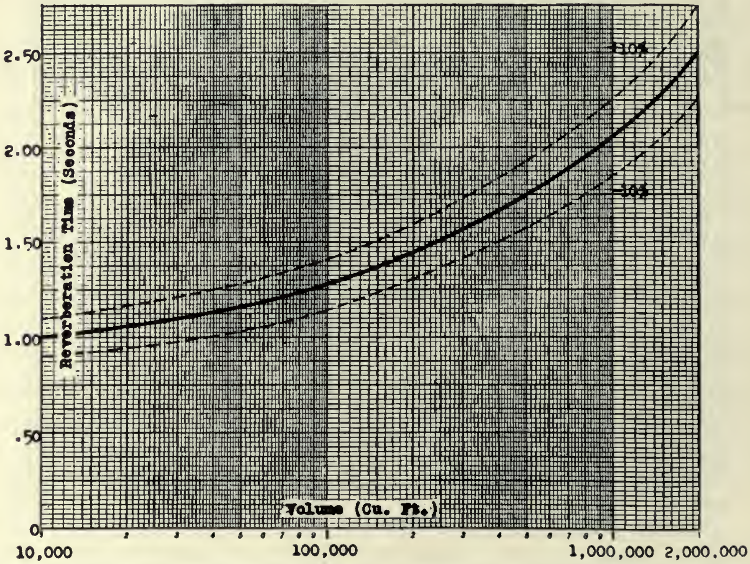


Fig. 2. Optimal reverberation time *vs.* volume, for reproduced sound at 512 cps.

materials. The use of highly upholstered seats is of particular value from an acoustic standpoint since, when unoccupied, they compensate to a large degree for absorption normally provided by the audience, and thereby assure a more uniform reverberation period for all variations in attendance. The use of such seats also appreciably reduces the quantity of other types of absorbing materials required. Plain wooden seats provide negligible absorption in comparison to the audience, and the use of such seats generally necessitates the application of a large quantity of acoustic material to compensate for the inefficiency of the seats and assure a desirable acoustic condition for average audiences. This frequently results in a slightly "dead"

condition, with maximum audiences, but still leaves the theater somewhat reverberant for small percentages of attendance. Fig. 1 shows a comparison of the general efficiency and acoustic characteristics of seats of several different types, relative to the average absorption characteristic of an individual present in the theater. These data are adopted from tests made by F. R. Watson[5] and W. C. Sabine. The seat tests were made only at the frequencies indicated. Extrapolation of the curves will give, within reasonable limits of accuracy, the relative absorption values at the other frequencies. From an

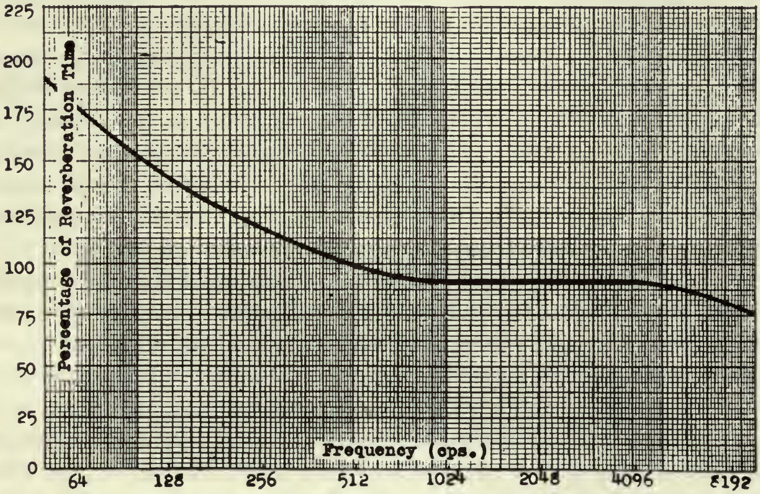


FIG. 3. Optimal reverberation-frequency characteristic, in per cent of reverberation time at 512 cps.

acoustic standpoint the effective volume per seat should preferably not exceed 150 cubic feet for the average theater.

The carpet used in the theater should be of a heavy grade, reinforced, which will effectively reduce impact noise as well as provide acoustic absorption. Drapes, such as those generally installed around doors, lobby openings, *etc.*, should preferably be heavy lined velour.

Having determined with all possible accuracy the total absorption contributed by the proposed seats, carpet, drapes, and other surfaces, and including the absorption provided by the probable average audience (we assume two-thirds of the seating capacity when using efficient seats), the introduction of this figure into the formula as a function of the enclosed volume and associated constants will indicate, within

reasonable limits of accuracy, the probable reverberation period of the proposed theater. This analysis should be made at octave intervals for frequencies ranging from at least 128 to 4096 cps.

(2) *Optimal Times of Reverberation.*—Fig. 2 shows an optimal reverberation time curve for reproduced sound at 512 cps., as recommended by Electrical Research Products, Inc., for theaters of satisfactory shape and proportions. Fig. 3 is a percentage curve which, applied to the optimal values of Fig. 2, will indicate the desirable reverberation time for frequencies other than 512 cycles per second. These optimal and relative percentage curves are based upon extensive theoretical and practical research comprising instrumental measurements in theaters both treated and untreated, articulation tests, and general observations of sound quality by competent critics. A deviation of ±10 per cent from the optimum is permissible, although the time should not exceed these limits for reproduced sound. In theaters to be used for direct, as well as for reproduced sound, the optimal reverberation time selected should preferably approximate the upper 10 per cent limit indicated on the curve in Fig. 2.

(3) *Frequency Distortion.*—This is a factor that warrants careful consideration, because the results to be attained, at present as well as in the future, due to progressive improvements in sound reproducing systems, will depend largely upon the general acoustic characteristic of the theater. The use of materials that provide a large amount of absorption at the high frequencies and only a small amount at the low frequencies, as explained later under the section on selection of materials, must be avoided unless they are to be used in conjunction with other types, the combination of which will produce the proper balance of absorption at all frequencies. The ear is less sensitive to low-frequency sounds than to high-frequency sounds; and, therefore, more reverberation is permissible at the low frequencies. This variation assumes certain definite limits, however, which must be maintained to avoid noticeable "boominess" at the low frequencies and excessive "deadness" throughout the higher portion of the frequency spectrum. Frequency distortion may be caused also by poor construction of the interior surfaces. If the surfaces are made of light-weight materials, they must be strongly braced to avoid pronounced resonance at certain frequencies.

(4) *Loudness.*—A level of operation consistent with good hearing conditions must be maintained throughout the entire seating area to assure the maximum degree of naturalness. Operating the sound

system at a high level increases the duration of reverberation and may cause distortion. To avoid these defects, all possible sources of internal as well as external noise must be checked and eliminated as far as practicable. The most common sources of internal noise, other than those already considered, are ventilating equipment—blowers, driving motors, fans; motor-generator sets; heating equipment; *etc.* Sound isolation of ventilating systems, motor-generators, and other equipment; lining ducts with efficient sound-absorbing material; and providing for insulative machinery bases where required, are effective methods for reducing internal noise from these sources.

SURFACE TREATMENT

(*1*) *Selection of Materials.*—The principal factors governing the selection of an acoustic material are (*1*) its characteristic, or absorption over the frequency range relative to other types of absorption within the theater; (*2*) its general efficiency for treatment of the surfaces under consideration; and (*3*) its adaptability to the proposed architectural and decorative scheme. Numerous kinds of acoustic materials in the form of tiles, felts, plasters, *etc.*, both fireproof and non-fireproof, have been developed within the past few years, providing a variety sufficient to fulfill practically every requirement from both acoustic and architectural standpoints. Continual progress is being made in the further development of these as well as newer materials, improving their acoustic efficiency and adaptability to various types of construction. Through the medium of the Acoustic Materials Association,[6] information pertaining to the efficiency of the various kinds of materials supplied by the leading manufacturers is available without cost. From a comparison of these, as well as other data, a material or combination of materials can generally be selected that will fulfill the requirements.

When selecting a material for acoustic treatment, particular consideration must be given to its absorption over the frequency spectrum. It will be found, from both analyses and measurements, that the fixed absorption, or that provided by carpet, seats, drapes, *etc.*, is generally high throughout the upper range, relative to its values at the lower frequencies. While smaller amounts of absorption are permissible at the lower frequencies, as will be observed from an analysis of Fig. 3, care must be taken to avoid introducing amounts of absorption appreciably below the desired limits at the low fre-

quencies or in excess of the requirements at the high frequencies. Fig. 4 shows the frequency-absorption characteristics of two typical acoustic materials having equal coefficients at 512 cps. The use of a large quantity of material *B* (Fig. 4) independently would result in extreme frequency distortion, causing a pronounced "boominess" at low frequencies and a most noticeable lack of brilliance at high frequencies. The increased average efficiency and more desirable characteristic of material *A* is particularly apparent, and may be regarded as falling well within the required limits for general theater use. Attention is called to the relative coefficients at 512 cps., and

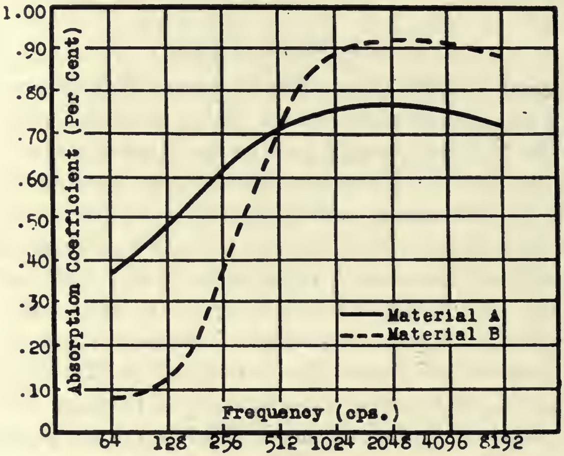


FIG. 4. Comparative absorption characteristics.

the importance of not considering this frequency only, when selecting acoustic materials for treatment. To approach an absorption characteristic approximating that obtained at the laboratory, the method of mounting the material for test should be carefully noted and followed accordingly when applying treatment.

(*2*) *Desirable Locations.*—The most desirable locations for the acoustic material are governed by the general shape of the theater and the relation of various surfaces to the sound-source. In theaters of satisfactory proportions, materials of high average absorption and favorable characteristics are most effectively placed upon the rear wall surfaces, particularly when these areas are of wide expanse and subject to considerable direct sound energy. The side walls,

extending forward from the rear wall, are generally the surfaces of next importance. The efficiency and extent of this further treatment for these areas are governed by the requirements of the particular theater under consideration. In theaters having balconies it is not generally necessary to treat the rear and side wall areas directly beneath the balconies unless the depth is less than approximately twice the height. When inefficient seats are used, a partial ceiling treatment of a material of moderate absorption and favorable characteristics is also desirable.

CONCLUSIONS

With due consideration to the fundamental requirements for acoustical design and treatment, it is possible to plan a theater in which hearing conditions will meet with the full satisfaction and approval of the patronage. The general business outlook and anticipated revenue from operation are largely dependent upon the quality and intelligibility of sound, since it has been determined from a careful survey that a large number of the theaters that fail financially are those that are noted for their undesirable acoustic conditions.

It is believed possible to standardize, for definite reference, certain of the data given above, in order that architects or engineers may be guided in solving the more common acoustic problems with which they are confronted. Our past experience in recommending the acoustical correction of more than 8000 theaters has indicated, however, that a large number of cases will arise in which standardized methods will not apply. In such cases and particularly those involving complete originality of design, reliable acoustic advice should be obtained before attempting the solution of problems that present any degree of complication.

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ANALYSIS OF SOUND WAVES*

H. H. HALL**

Summary.—*Most sounds consist of a spectrum of frequencies of various intensities. The distribution of the frequencies and intensities determines the quality of the sound. The spectrum may remain fairly constant in time, or it may go through rapid changes. Sound analysis is the process by which the various components of the spectrum are detected and measured. A complete analysis should furnish the frequency and amplitude of each component as well as its phase relatively to the other components, at a given instant of time. If the spectrum changes in time, a complete analysis should be made at intervals throughout the duration of the sound, the lengths of the intervals being determined by the rate at which the spectrum is changing.*

For purposes of analysis sounds may be grouped into four classes: (1) sounds that may be maintained at constant frequency, constant intensity, and unvarying quality for a period long enough to carry out the analysis; (2) sounds that are essentially transient in nature; (3) sounds that may be maintained constant, on the average, but whose frequency, intensity, and quality vary periodically within this time; (4) sounds that are entirely random in form but are continuously maintained. The first two groups of sounds require different methods of analysis. The third group in certain instances may be analyzed by the methods used for class 1, whereas in others the method used for class 2 may be necessary. Sounds of class 4 may be analyzed by all methods capable of analyzing sounds of class 1 with one exception.

Instruments for analysis may be grouped into five classes: graphic, resonance, heterodyne, stroboscopic, and diffraction analyzers. The operation of each type of instrument is briefly discussed and the suitability of each for analyzing the various classes of sounds is brought out. Examples of analyses performed by the various methods are presented.

It is well known that any wave may be represented by the sum of a series of sine waves of different frequencies whose amplitudes and relative phases are determined by the form of the original wave. Such a series of simple waves constitutes the spectrum of the wave, and, in the case of sound, the detection and measurement of the components of this spectrum are sound analysis.

It follows that an ideal analysis must furnish the following data, referred to a specific instant in time:

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* Presented at the Spring, 1936, Meeting at Chicago, Ill.

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(*1*) The frequencies of all components.
(*2*) The relative amplitudes of the components.
(*3*) The relative phases of the components.

If these data are known the original wave may be reproduced precisely. The human ear, however, is not sensitive to phase, and a specification of the frequencies and amplitudes, therefore, is often sufficient.

CLASSIFICATION OF SOUND WAVES

Although musical sounds consist of a chain of nearly identical waves, other sounds are by no means of such nature. Even vowel sounds sung by a well trained voice exhibit more or less regular fluctuations of frequency, intensity, and wave-form while maintained on one note. In ordinary speech the frequency, intensity, and wave-form vary rapidly during the speaking of a single syllable, while in the case of noise such as the roar of heavy traffic or background noise in a sound-reproducing system, the waves are entirely random in form but have definite characteristics when averaged over a sufficiently long time. Other sounds of short duration, such as the slam of a door, may have definite characters but are completely transient in nature.

From the point of view of analysis, sounds may be classified roughly into four groups:

(*1*) Steady-state sounds, or sounds that may be maintained at constant fundamental frequency, constant intensity, and unvarying quality for periods long enough to carry out the analysis.

(*2*) Sounds that are essentially transient in nature.

(*3*) Sounds that may be maintained constant, on the average, but whose frequency, intensity, and wave-form are modulated at a constant frequency.

(*4*) Noise, or sounds that are entirely random in form but which are continuously maintained.

Regarded as spectra, the sounds of type *1* represent an array of components whose frequencies are integral multiples of the fundamental frequency, and whose amplitudes are determined by the character of the sound. Sounds of type *2* represent continuous spectra embracing all frequencies within wide limits. If the transient sound of this type endures for a fairly long time and varies but slowly, the distribution of amplitudes will be such as to emphasize frequencies in the neighborhood of those that would constitute the spectrum of the steady-state wave to which the transient wave is momentarily similar, and to suppress the others. As the wave changes, the amplitude distribution changes accordingly. Sounds of type *3* are strictly steady-state

waves, if the modulation frequency be taken as the fundamental. On the other hand, if this frequency is negligible with respect to that of the fundamental of the unmodulated wave, the wave may be regarded as one whose frequency and form vary periodically. But the two representations of the wave are equivalent. The latter point of view, however, does not represent a complete resolution of the wave.

METHODS OF ANALYSIS

When the form of a given wave may be expressed as a mathematical function or is available as a plot of displacement against time, the

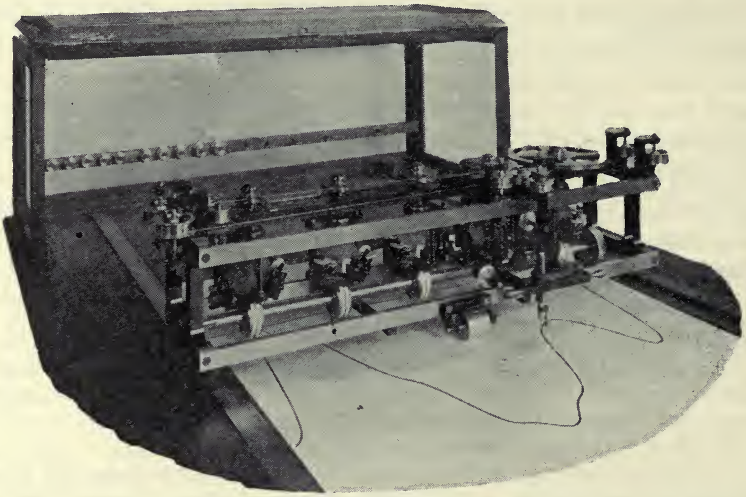

FIG. 1. The Henrici Analyzer. After the index stylus has been made to trace the curve, the amplitudes of the first five sine and cosine components may be read on the proper dials. A second tracing furnishes the next five, and so on up to fifteen pairs of components. (*Courtesy of D. C. Miller.*[1])

analysis may be made by direct computation. This is a laborious process, which may be avoided under proper conditions by employing instrumental methods. Instruments designed to accomplish it are based upon a number of different processes and may be classed as follows:

(*1*) Graphic Analyzers.
(*2*) Resonance Analyzers.
(*3*) Heterodyne Analyzers.
(*4*) Stroboscopic Analyzers.
(*5*) Diffraction Analyzers.

GRAPHIC ANALYZERS

The graphic analyzer requires that the wave be recorded as a curve of displacement against time. The curve is enlarged to proper dimensions and placed upon a horizontal board over which the analyzer may travel. A form of this instrument, the Henrici analyzer, shown in Fig. 1, has been described by Miller.[1] The stylus of the analyzer is made to trace the curve, and the frequencies and amplitudes of the components may be read on the proper dials. Amplitudes of sine and cosine series are given, which is equivalent to specifying the amplitudes and phases of a single series. In this way the first five

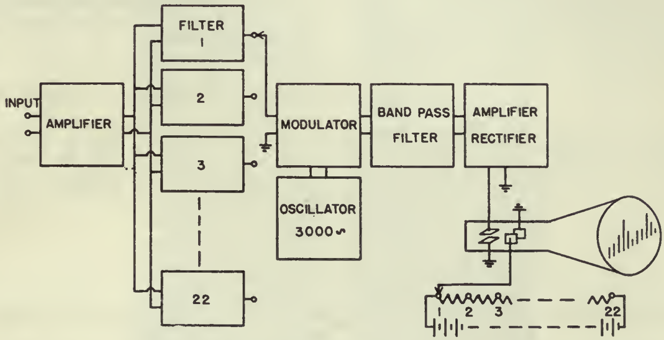

FIG. 2. Freystedt's resonance analyzer. The switch connecting the filters to the measuring circuit and that connecting the horizontally deflecting plates of the cathode-ray tube to the battery are rotary, and are mounted upon the same shaft. The oscillator changes the whole frequency band by heterodyning to a more convenient range. (*After E. Freystedt.*[4])

components of the wave are given. Retracing the wave with a different setting of the instrument furnishes the next five, and so on up to fifteen components.

The method assumes that the spectrum consists of components whose frequencies are integral multiples of that of the fundamental. This is true only for steady-state waves. The instrument, therefore, may not be used to analyze one wave taken from a rapidly varying transient sound. If the sound varies slowly enough, analyses may be made affording an approximation to the true spectrum that becomes better the slower the variation.

RESONANCE ANALYZERS

Suppose the frequency range that it is desired to analyze be divided by small steps into a large number of frequencies, and that an array of vibrating reeds be provided, one tuned to resonance at each frequency. If a complex steady-state wave is applied to this assembly, the reeds whose frequencies are nearest those of components of the wave will be set into motion, and their amplitudes will depend upon the amplitudes of the components. Such an instrument[2] will furnish the frequencies and amplitudes of the components, but not their relative phases. Other resonators may replace the reeds, such as elec-

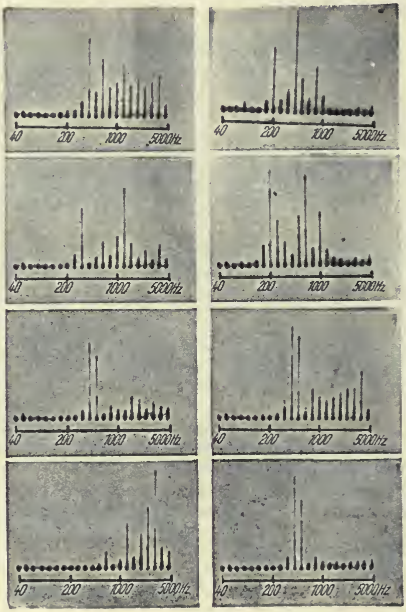

FIG. 3. Analyses of violin sounds made with Freystedt's analyzer. (*Courtesy of Johann Ambrosius Barth.*[4])

trical tuned circuits, tuned air chambers,[3] or band-pass filters. Fig. 2 shows schematically an instrument of the last type, described by Freystedt.[4] There are in all twenty-two band-pass filters, three per octave, covering the range from 40 to 5500 cps. The outputs of the filters are connected one after another through a switching mechanism to the vertically deflecting plates of a cathode-ray tube. As the tube is switched from one output to another, the spot is moved a short distance horizontally, so that the pattern traced upon the screen of

the tube is a series of vertical lines whose heights are proportional to the outputs of the filters and whose positions correspond to their frequencies. Fig. 3 shows some analyses made with this instrument. This form of analyzer is not subject to the arbitrary assumptions that apply to the graphic analyzer, because it responds to whatever frequencies are actually present in the wave, whether harmonic or not.

If a periodic force is applied to a resonator at its frequency of resonance, it is well known that the amplitude of vibration of the resonator builds up gradually to a maximum at a rate that depends upon the damping. The increase of amplitude is rapid if the damping is large, and slow if the damping is small. An appreciable time is therefore required to excite the resonators to full amplitude. On the other hand, if the resonator is to discriminate sharply between the resonance frequency and neighboring frequencies, the damping must be small. The designer of such an instrument must therefore choose between rapid response and resolving power.

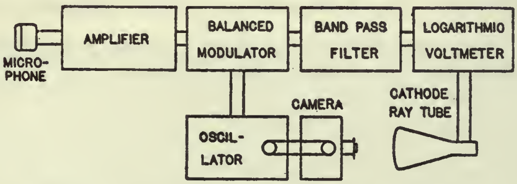

FIG. 4. Diagram of heterodyne analyzer.

HETERODYNE ANALYZERS

The multiplicity of resonators of the resonance analyzer can be avoided by heterodyning. Referring to Fig. 4, the wave to be analyzed and a wave whose frequency can be varied are applied together to a detector or non-linear circuit element. The output of the detector will contain new components whose frequencies will be the differences between those of the applied wave and that of the variable wave. When the frequency of the latter is varied this group of components will vary with it. It is thus possible to require only one resonator or filter responding to a narrow band of frequencies, and to vary the frequencies of the difference-frequency band which, one by one, will actuate the resonator. This, in turn, operates a recording device. It may be shown that the amplitudes of these components are proportional to those in the original wave. This is often called the "search tone" method of analysis. Fig. 5 illustrates such an analyzer built by the author,[5] and Fig. 6 shows representative analyses

FIG. 5. The heterodyne analyzer built at the Cruft Laboratory.

made with it. The amplitude of each component relative to the fundamental is measured upon the vertical scale. The response is logarithmic, and the range of amplitude is 60 decibels, or 1000 to 1. The horizontal scale is frequency. The analyses are of the first eight cardinal vowels intoned by a male voice. Each peak indicates the presence of a component. The last example is an attempt to analyze the sound *S*, which is a sound of type *4*, and is seen to consist of a continuous distribution of frequencies ranging from about 4500 to at least 10,000 cps. The fluctuations are low-frequency time varia-

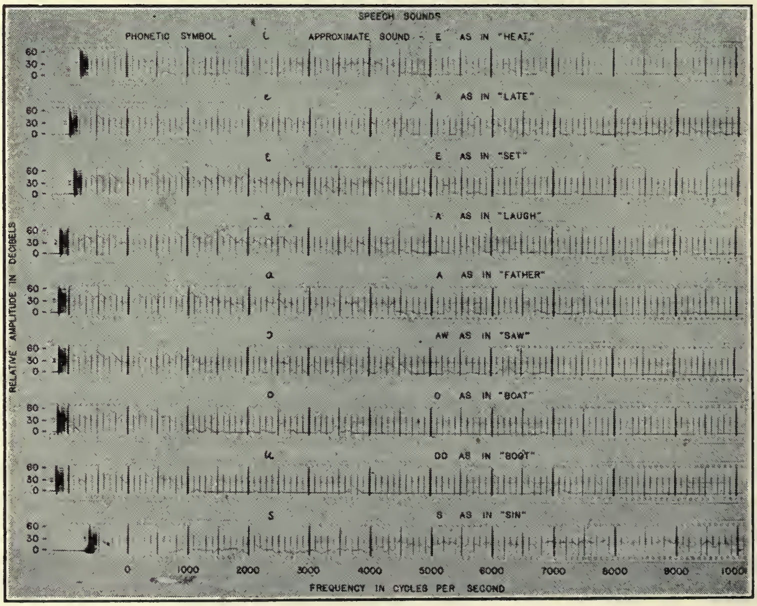

FIG. 6. Analyses made by the Cruft Laboratory analyzer. The sounds are the first eight cardinal vowels intoned by a male voice. The sound *S*, in the last analysis, is seen to consist of a continuous distribution of frequencies of sufficient intensity to be important from about 4500 to at least 10,000 cps.

tions of amplitude which cause the output of the analyzer to fluctuate as the analysis is made. An envelope covering the whole distribution is the only characteristic having a meaning in this case.

It is at once clear that an analysis can not be made instantaneously by this method, because the resonator requires appreciable time in which to reach full amplitude of vibration after the wave has been applied. This period, moreover, must elapse as many times as there are components to be measured. The method of analysis is therefore slower than the resonance analyzer method, because the various resonators in the latter are excited simultaneously. It has the advantage, however, of simpler construction and of being capable of indicating any frequency in a continuous range instead of a range divided into finite steps. The time required for the analysis, and, therefore, the time during which the wave may not depart appreciably from a steady state, may be shown to be proportional to the square of the resolving power of the instrument. Nevertheless, quite rapid analyses may be made with the heterodyne analyzer. The analyzer mentioned above will cover the range of 50 to 10,000 cps. in less than four seconds, and yet resolve components only 50 cycles apart, if they are of the same amplitude. Another instrument described by Schuck[6] makes analyses in about one-tenth of a second with a corresponding reduction in resolving power.

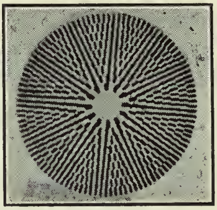

FIG. 7. Stroboscopic disk for analysis, designed to analyze the first nine components of a steady-state wave when illuminated by light whose intensity is controlled by the wave to be analyzed. (*From T. de Nemes,*[7] *Courtesy of Julius Springer.*)

STROBOSCOPIC ANALYZERS

As described by de Nemes[4] a rotating disk may be used for wave analysis. The face of a disk is divided into concentric rings, as shown in Fig. 7, and each ring is divided into segments alternately black and white. The second ring from the center of the disk has twice as many segments as the first ring, the third three times as many, and so on. The disk is rotated at a constant speed fast enough to cause the segments of the first ring to pass a given point at a frequency equal to the fundamental frequency of the wave to be analyzed. If the disk is illuminated by light whose intensity is varied to correspond to this wave, the rings corresponding to components present in the wave will

appear to stand still. This assumes, of course, that the wave is in a steady state, and that only component frequencies that are integral multiples of the fundamental frequency are present. The variation of light intensity is accomplished by using a neon lamp modulated by an amplifier to which the wave to be analyzed is applied. The in-

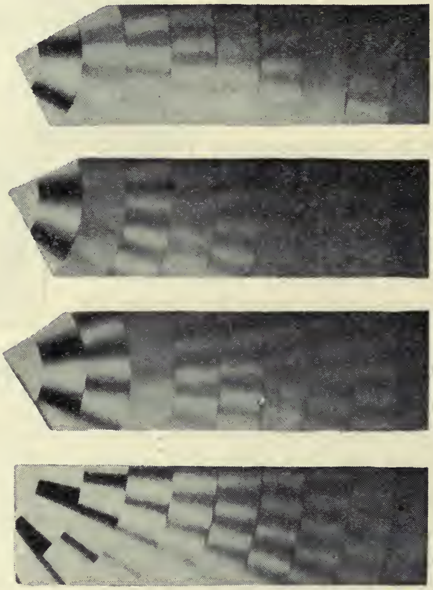

FIG. 8. Analyses made by the disk shown in Fig. 7. The rings that are entirely blurred show the absence of the corresponding components in the wave. Note the difference in phase between the fundamental and the next component, in the first example. (*From T. de Nemes,*[7] *Courtesy of Julius Springer.*)

strument indicates phases very nicely, but the intensities of the components are not clearly given. Fig. 8 shows analyses of steady tones made in this way by de Nemes. The smallest ring, of which only a segment is shown in each case, corresponds to the fundamental. The presence of higher components is indicated wherever a ring appears to stand still. In the photographs the rings that are completely blurred represent components that are absent.

DIFFRACTION ANALYZERS

There are two types of diffraction analyzers, one of which employs diffracted sound, and the other diffracted light. An example of the first type, described recently by Meyer,[8] makes use of a diffraction grating designed for sound-waves. Since the wavelength of audible sound may be several meters, and since the grating space must be comparable in width to one wavelength, it is necessary to change the wavelengths to more convenient values. This is done by heterodyning by a fixed-frequency oscillator. In this case the heterodyne frequency is 45,000 cps., applied to a detector simultaneously with the wave to be analyzed. The resulting band of sum frequencies is amplified and applied to a small ribbon loud speaker. The sound falls upon a concave grating made of steel rods, 3.4 mm. in diameter and spaced 3 mm. apart, as shown in Fig. 9. The rods are mounted in

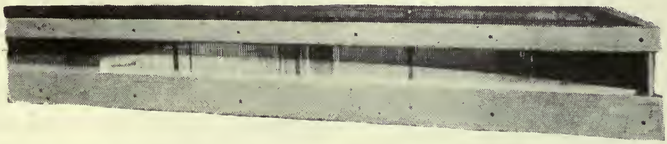

FIG. 9. Meyer's diffraction grating for sound. The elements are steel rods 3.4 mm. in diameter and 3 mm. apart. (*From E. Meyer,*[8] *Courtesy of J. Acous. Soc. Amer.*)

two parallel iron plates 12 cm. apart, the whole grating being some three meters long. It has a theoretical resolving power of 125 cycles and a dispersion of 8 cm. per kilocycle. To observe the spectrum produced, a small condenser microphone is moved through the region in which the spectrum lies, and the output controls an oscillograph. Figs. 10 and 11 show analyses made in this way.

The beauty of the method lies in the very short time required for the spectrum to be formed. This interval is the difference between the times required by the sound to travel from the nearest and farthest grating apertures to the microphone. Meyer gives one 0.01 second for this time. Theoretically, at least, it would be possible to observe the spectrum of a rapidly varying sound, which should appear as a continuous spectrum. Unfortunately, this is difficult to carry out because there is nothing that is as sensitive to sound as the photographic plate is to light. Using the small microphone, however, a total analyzing time of approximately 0.1 second is obtained, which Meyer states is limited by photographic considerations.

Another ingenious diffraction analyzer makes use of diffracted light to produce the spectrum. Observation of the spectrum produced by a diffraction grating may be used to study the form of the grating. Thus, when monochromatic light is used and the spectrum contains in addition to the single bright line a number of "ghosts," the imperfections of the grating may be computed from the positicns and intensities of the ghosts. If a grating were made, the width of whose lines were varied in accordance with the wave-form to be analyzed, then with monochromatic light a spectrum of ghosts would be produced that would be characteristic of the wave. This has been accomplished by Germansky[9] in the following manner: The polished metal surface upon which the grating is to be made is covered with a thin coating of a mixture of glue, ammonium bichromate, and chromic acid, which has the property of becoming insoluble in water when exposed to light. A variable-density photograph of the wave to be analyzed is prepared, and the treated metal surface is exposed to light that has passed through the variable-density reproduction of the wave and a fine screen of alternately transparent and opaque parallel lines perpendicular to the axis of travel of the wave. After exposure, the unaffected coating of bichromate and glue is washed off, leaving a grating, the widths of whose lines vary in the desired way. The method is similar to that by which ordinary halftone plates are produced, except that a screen of parallel lines is used instead of a fine mesh. Such an analyzer has the advantage that the spectrum may be recorded directly upon a photographic plate. In the state in which it was described, the method can not compare with the sound diffraction analyzer; yet, if there were some means of producing the grating simultaneously and continuously with the sound, the scheme would have a number of advantages.

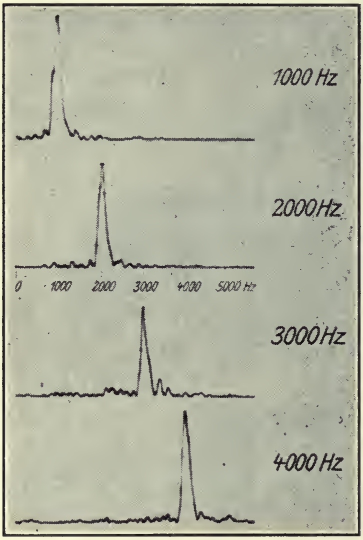

FIG. 10. Analyses of pure tones with Meyer's grating. (*From E. Meyer,*[8] *Courtesy of J. Acous. Soc. Amer.*)

CLASSIFICATION OF ANALYZERS

Perhaps enough material has been given in this brief discussion to furnish a basis upon which the various types of analyzers may be classified. Such a classification is given in Table I.

All types of analyzers are capable of analyzing sounds of class *1*, or steady-state sounds. Sounds of class *2*, or transient sounds, may strictly be analyzed only by diffraction analyzers. But if the tran-

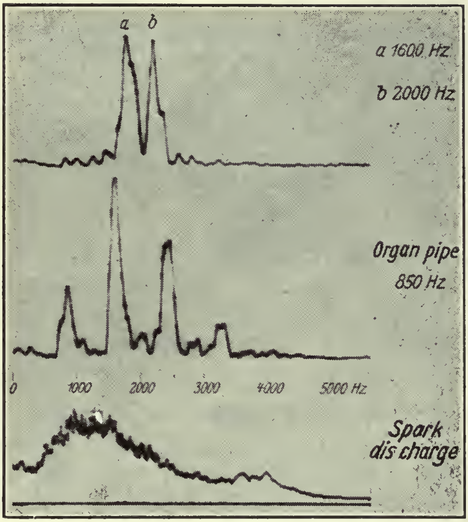

FIG. 11. Analyses of various sounds made with Meyer's grating. (*From E. Meyer*,[8] *Courtesy of J. Acous. Soc. Amer.*)

sient sound varies slowly, the resonance and stroboscopic analyzers may be used. If the time of analysis is sufficiently short, the heterodyne analyzer may be used. If the variation of the transient is sufficiently slow, the graphic analyzer will give the steady-state spectrum to which the sound approximates at any given instant.

Any analyzer capable of analyzing a steady-state wave, provided it has sufficient resolving power, is effective in analyzing sounds of class *3*. If the frequency of modulation is negligible compared to that of the unmodulated fundamental, then it is permissible to use a graphic analyzer to analyze selected waves taken at different instants in the modulation cycle. But these analyses will be those of the steady-

state wave to which the wave under investigation is instantaneously similar.[10] Sounds of class *4*, which represent continuous spectra, can be analyzed by all analyzers, with the exception of the graphic and stroboscopic types.

TABLE I

Classification of Analyzers

Type	Input	Time for Analysis	Waves Analyzed	Results
Graphic	Oscillogram	1 hour	Steady-state Slowly varying Transient	Frequency Amplitude Phase
Resonance	Microphone	0.1 second Proportional to resolving power	Steady-state Slowly varying Transient	Frequency Amplitude
Heterodyne	Microphone	4 seconds Proportional to square of resolving power	Steady-state	Frequency Amplitude
Stroboscopic	Microphone	0.05 second	Steady-state Slowly varying Transient	Frequency Phase
Diffraction	Microphone	0.01 second	Steady-state Transient	Frequency Amplitude

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THE TECHNICAL BASIS OF X-RAY MOTION PICTURE PHOTOGRAPHY*

R. JANKER**

Summary.—*After considering the difficulties involved in the direct method of x-ray cinematography, in which the x-rays penetrate the subject and pass directly to the photographic film with intensities depending upon the absorption of the subject, some of the work done by the author by means of the indirect method is described. In the indirect method, the x-ray image of the subject upon the fluorescent screen is photographed in reduced size by means of a suitable lens system. Various difficulties and factors of the system to be considered are discussed, and examples of the results attained by the indirect method are presented.*

The desire to render visible the activities of the internal organs by means of x-ray motion pictures is almost as old as the knowledge of x-rays themselves. A method of doing so was first proposed in the year in which Röntgen published his discovery, but only recently has it actually become practicable. Technical difficulties have been responsible for the failure of the accomplishment to catch up with the desire.

When we wish to record and reproduce movement in a picture we divide it into 16 to 18 separate phases per second. Upon projection, the human eye can no longer separate the individual pictures as rapidly as that, so we have the impression of motion.

Now let us consider how an x-ray picture is produced. Rays emitted from an x-ray tube penetrate the object, and, depending upon the thickness and composition of the object, undergo more or less weakening by absorption. Proceeding in straight lines, the rays strike the photographic emulsion and produce an image of the object by virtue of their differing intensities. The size of the image corresponds closely to that of the object; but actually, because the rays are projected from a small source, the image is somewhat larger than the object. If, for example, it were desired to photograph the human thorax by means of x-rays, it would be necessary to use a film 30 cm. long and 40 cm. wide. Since 16 to 18 pictures per second are required, in one second

*Presented at the Spring, 1936, Meeting, Chicago, Ill.

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16 to 18 times an area of 30 × 40 cm. of film would be used; *i. e.*, a strip of film 40 cm. wide and from 4.8 to 5.4 meters long per second. Construction of a projector in these proportions is out of the question, and for projection in existing apparatus, the image must be reduced to normal size. It does not need to be emphasized that the cost of the materials in the large size would be prohibitive.

In this so-called *direct method* (Fig. 1) there are still other appreciable technical difficulties. The film band must be moved intermittently 16 to 18 times per second through the length of a frame (30 cm.), and must be stopped and exposed during each stationary period. Furthermore, it would be necessary to abandon the use of intensifying screens; a thing that could not be tolerated for such short exposures, since the fluorescence augments the photographic effect of the x-rays considerably. These screens would have to be pressed flat against the film by means of plates, and both plates and screens carried along together by the film; or they would have to be raised from the film from 16 to 18 times per second while the film is moved, and then pressed against the film during each exposure period. Difficult problems of construction would be created by the necessity of moving such large amounts of material back and forth. A number of attempts have been made to solve this problem. It was necessary to restrict the pictures to small objects, and, therefore, to small film sizes, such as I used in photographing guinea pigs and similar animals at 22 frames per second, or else to photograph large objects over such very short intervals of time that the process can not really be spoken of as motion picture photography.

Another method gives much better results: *indirect x-ray motion picture photography* (Fig. 2). The x-ray image on a fluorescent screen is photographed in reduced size by means of a suitable lens system. In this method an entirely new difficulty arises. When it is considered how much illumination is required for taking pictures in the studio, it is readily understood that the brightness of the ordinary fluorescent screen is quite inadequate for instantaneous exposures. It should be remembered that the physician who wishes to view such a fluorescent image has to become adapted to the dark for at least a minute. Even with the greatest intensity attainable with modern x-ray apparatus, the screen brightness is much too low. In my first experiments in 1926, in spite of 10 seconds' exposure for each photograph, the results were not satisfactory. Therefore, in order to obtain 16 to 18 pictures per second, not only must the fluorescent screen operate under

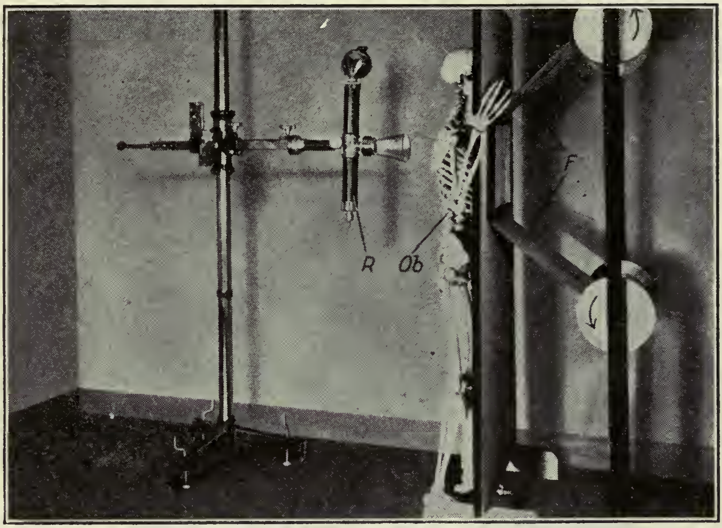


FIG. 1. Schematic arrangement for direct x-ray cinematography; *R*, x-ray tube; O_b, object; *F*, film.

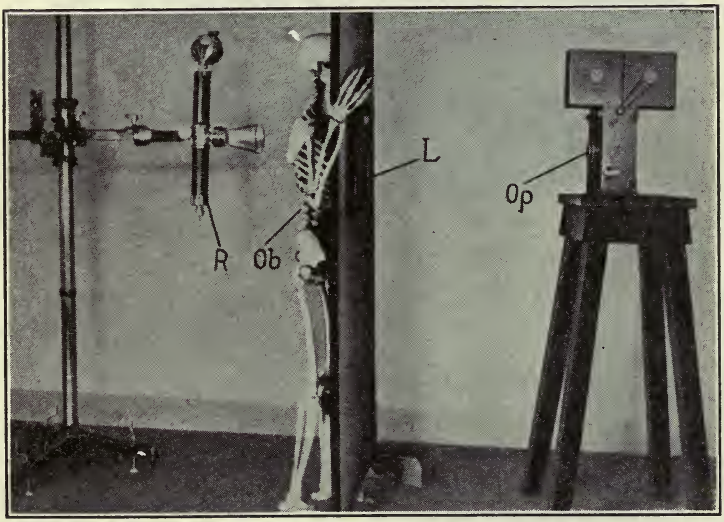


FIG. 2. Schematic arrangement for indirect x-ray cinematography: *R*, x-ray tube; O_b, object; *L*, fluorescent screen with image O_p, motion picture camera.

optimal conditions, but other features of the method must be greatly improved. The following factors are to be considered:

(*1*) X-ray apparatus
(*2*) X-ray tube
(*3*) Fluorescent screen
(*4*) Lens system
(*5*) Motion picture camera
(*6*) Film

With systematic work over several years, considerable progress has been made. It is possible in this paper to refer only briefly to the various points.

(*1*) At first, ordinary commercial x-ray apparatus was used; however, the power was too low for the purpose, chiefly because the equipment did not produce the necessary current intensities at high potentials. Finally, a suitable x-ray generator with a supplementary condenser was built. Its details will not be discussed here.

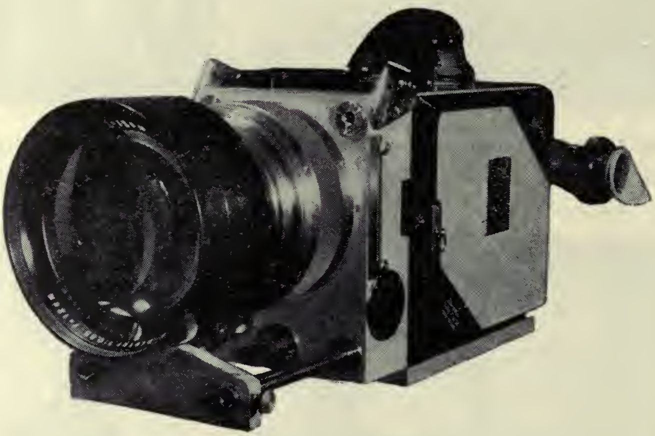


FIG. 3. Zeiss $f/0.85$ lens, on Askania x-ray camera.

(*2*) The available x-ray tubes did not fulfill the requirements. Thanks to the aid of the firm of Siemens, we now have tubes with revolving anodes, which, in spite of the greatly increased power load, have a relatively small focal spot capable of producing sharp definition in the x-ray image.

(*3*) To obtain the best available fluorescent screen, samples of both domestic and foreign manufacture were tested. First of all,

on account of the variations in spectral quality of the fluorescent light, each screen had to be tested with films of various sensitivities in order to find the most satisfactory combination. At the present time we are using a special make of Heyden and Siemens screen.

(*4*) Particular trouble was encountered in producing a lens of sufficiently high aperture. Considerable progress was made with a Zeiss *Biotar* $f/1.4$ lens, although we were not satisfied with it or with an $f/1.0$ lens that the Ruo Werke succeeded in making. We hope that the lens in use at present, the Zeiss $f/0.85$, for substandard and standard films (focal length 5.0 or 12.0 cm.) does not represent the final improvement from the German optical industry.

(*5*) The motion picture camera was so designed that with a constant picture frequency the pull-down time was made as short as possible in order to lengthen the exposure time of the individual

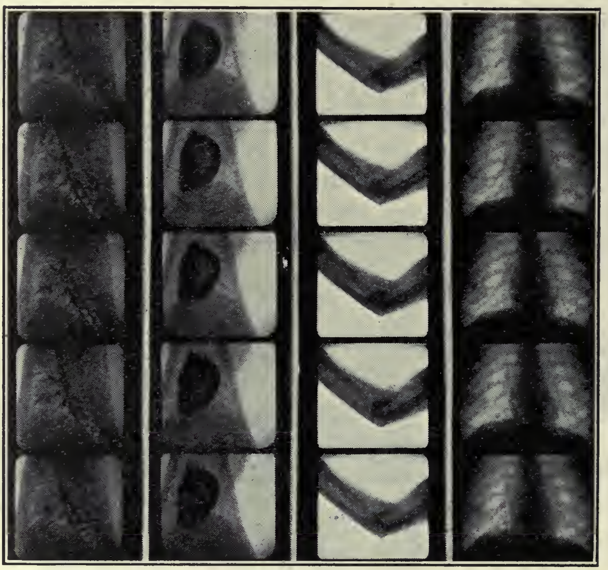
FIG. 4. Askania camera with drive for various speeds and time-lapse attachment.

pictures. During the earlier years we worked to the extreme limits of this principle, with a camera we constructed ourselves, having no shutter and a pull-down speed not reached heretofore. Now we use a camera built by the Askania Works according to the author's specifications, in which the time is not shortened nearly so much (270-degree light sector, 90-degree dark sector) (Figs. 3 and 4).

(*6*) At first, the best films obtainable were not nearly sensitive enough for x-ray motion picture photography. We therefore attempted to sensitize the films ourselves, but because of the difficulties involved we no longer do so. We now use the commercial materials, Kodak *Panatomic* film and Agfa *Pankine H* film.

Through the continued improvement of these factors it has been possible to produce a large number of experimental films of animal subjects and a number of films of human beings (Fig. 5). The quality of the pictures became improved with experience, particularly by

increasing the distance between the x-ray tube and the object. This was kept as small as possible at first, with the aid of insulating layers between the patient and the (high-tension) tube, in order to attain a sufficient x-ray intensity (which decreases as the square of the distance). Associated with this short distance was some degree



(*a*) (*b*) (*c*) (*d*)

FIG. 5. Examples of x-ray cinematography:
(*a*) Bronchial tree of cat, after injection of contrast solution.
(*b*) Injection of contrast solution into pericardium of cat.
(*c*) Movement of elbow joint in myositis ossificaus.
(*d*) Human heart and lungs.

of haziness of the image. Now we can work at distances great enough to afford satisfactory image quality.

During the course of the year, partially through the support of the German Science Notgemeinschaft and of a group of friends and promotors at the University of Bonn, it was possible to make many improvements and develop more extensive facilities for x-ray motion pictures. Too much space would be required to describe all these details. Two pictures with brief comments (Figs. 6 and 7) are included here, of those made so far.

There is still another difficulty that has not been mentioned: the

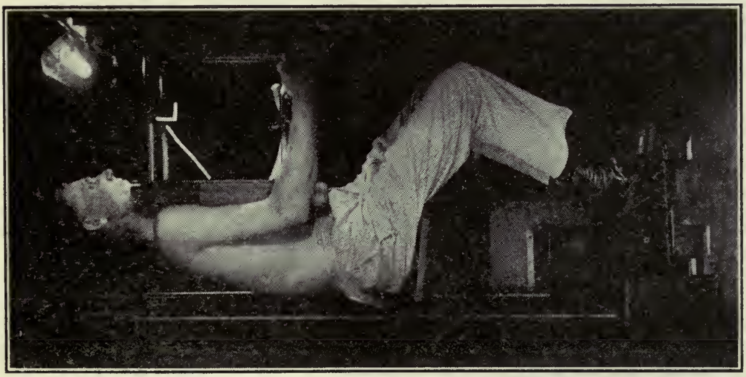


FIG. 6. View of booth for photographing human beings.

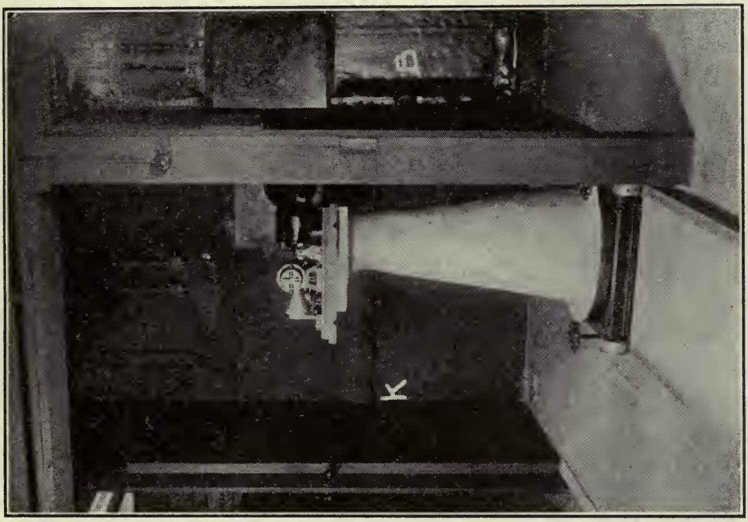


FIG. 7. Lead-protected observation booth and sound recording room (B), and space for support and camera for photographing human beings (K).

danger of higher and higher x-ray dosages to the subject. Man can tolerate only a certain quantity of x-rays. If this amount is exceeded then more or less serious changes in the skin and the internal organs occur. It is only necessary to mention that these changes are practically irreparable and incur the risk of cancer later.

On this account no exposures are given that can harm the patient in any way. The limit of permissible radiation is reached in 50 seconds of motion pictures. Actually, however, one should keep well below this limit so that in no case will the exposures exceed 15 or, at the most, 20 seconds. For that reason, the next step in x-ray cinematography should be a further reduction of the intensity required, so that this method, using the longest possible lengths of film, can be added to the present roentgenological methods without endangering the patient. In this way, the procedure should offer a very important advancement in diagnosis.

It will be obvious that we have made use of other developments in technic, such as time-lapse and high-speed studies. Naturally, special apparatus was required. In time-lapse work (for example, one frame per second, with projection at normal speed) arrangements have to be made to expose a picture every two seconds. By means of commutators coupled to the camera, the x-ray apparatus is made to operate intermittently. In this way it is possible to record movements such as intestinal action extending over a period of some hours, and to reproduce the characteristic movements by projection at normal speed. On the other hand, with the high-speed camera, by photographing at a greater-than-normal number of frames per second and projecting at the normal rate, very rapid movements such as the contractions of the heart, which are difficult to analyze because of their rapidity, can be studied in detail. As early as 1932 we were able to take 100 pictures per second of a rabbit's heart. Unfortunately, at present we do not have a high-speed camera available; otherwise, we should be able to work at 200 or 300 pictures per second. With our present Askania camera we have already photographed the human heart at 50 frames per second. The camera is not mechanically suitable for greater speeds; otherwise, we should certainly have done work at higher speeds.

The problems of x-ray motion picture photography are not yet exhausted. Sound and picture can be recorded simultaneously; for example, the movement of the soft palate, epiglottis, and larnyx can be taken simultaneously with speech.

By way of special scientific experiments, the passage of the blood-stream can be followed with x-ray photographs. X-ray motion picture photography has become a scientifically exact and useful method of investigation. The films of animal experimentation and of human beings obtained by the Reichsstelle für den Unterrichtsfilm show briefly what it is possible to do as a means of instruction.

(At the conclusion of the paper a short 16-mm. x-ray sound motion picture was shown. It included several examples of the vocal organs of males and females. Details of tongue and other fleshly portions of the head were shown clearly as well as the bone structure.)

NOTE

The scientific work described in the foregoing article was carried out by Prof. Janker of the Chirurgische Institut of the University of Bonn and supported by the "Reichsstelle für den Unterrichtsfilm, Gemeinnützig G. m. b. H."

The Reichsstelle für den Unterrichtsfilm is an official body, supported by the German Government. One of its main tasks is to supply educational and scientific films for use in all types of German schools, including elementary schools, high schools, and universities. The schools are obliged to purchase their taking apparatus and projectors through this body, which will then assist them with their advice. The Reichsstelle für den Unterrichtsfilm is connected with technical departments at the technical high school of Berlin-Charlottenburg which deal with standardization questions concerning apparatus and films for the above-mentioned purpose.

From the establishment of the Reichsstelle für den Unterrichtsfilm in 1934, to February 28, 1936, 7037 16-mm. equipments have been delivered to German schools and 29,985 prints having an aggregate total length of 3,598,200 meters of 16-mm. film have been released for school purposes. This body also supports the scientific work of the German universities and technical high schools, of which the foregoing paper is an example.

The official journal of this institution is *Film und Bild*, in part 2 of which (1936) this paper was first published.

DISCUSSION

MR. CRABTREE: I have been wondering whether the doses used to obtain these pictures were fatal or not.

MR. AUTEN: Suitable x-ray dosages are not dangerous to the patient. The dosage can be so regulated that exposures up to thirty minutes are quite safe. Of course, it is rather dangerous to the physician because he spends his whole lifetime in the work, but not to the patient.

MR. TOENNIES: Physicians are always very careful to shield themselves against the x-rays. The doses given to the patients are near the danger point. X-ray cinematography is always very dangerous, because the intensity necessary for the time of shooting is much greater than that required for an ordinary still picture. Damage done by excessive doses can appear after a couple of years, in the form of cancer, for which at this time no cure is known. Injury is possible also when no skin burning has occurred. Young persons are in greater danger than

older ones. No motion picture engineer should work in this field without the advice of an x-ray expert.

MR. ROBERTS: Referring to the method described in the paper, the voltage on the tube is so great that probably many of the x-rays will pass through the screen. I wonder whether any trouble was experienced with the rays getting into the camera, upon the film, and perhaps into the lens.

MR. MORTON: The back of the fluorescent screen is covered with a heavy sheet of lead glass which prevents the x-rays from reaching the camera.

MR. TUTTLE: Guinea pigs used in our work have died from burns after five minutes of continuous exposure. They do not die immediately, but within a week or so. Of course, the x-ray tubes are tremendously overloaded to get the exposures we want: about 300 ma., 80 kv., at 14 inches. We have not subjected human patients to x-rays for longer than two minutes over a period of two or three months, and only for short exposures about 35 seconds each time.

To keep the x-rays out of the camera, we built a special lead shield with a socket that fits right around the lens, so the camera is virtually shielded from x-rays. We also used a lead glass in conjunction with the intensifying screen.

MR. WOLF: Does the person exposed to x-rays recover completely after intermittent exposure, or is there always some damage done by exposure?

MR. TUTTLE: I can not answer the question conclusively. I know that, in the case of doctors and technicians who have spent a long time at the work, and are affected only slightly, getting completely away from x-rays for six months seems to restore their health. I do not know anything about the time of recovery or the possibility of recovery if they are actually burned. Slight burns cause loss of hair and a redness of the skin that may never entirely heal. Long exposures or serious burns affect the bone marrow. With this kind of burn a person may live three or four years. Much depends upon their general health and other factors. In any case, it is extremely dangerous to use x-rays on human subjects, and they should not be used without medical advice.

A FILM EMULSION FOR MAKING DIRECT DUPLICATES IN A SINGLE STEP*

W. BARTH**

Summary.—*Duplicates of positives or negatives can be made by the familiar process of exposure, standard development, and fixation of a single film without requiring second exposure and development, as in the case of amateur motion picture reversible film, or resort to the duplicate negative process. Contact printing is required with exposures about equal to those used in printing chloride photographic paper emulsions. The emulsion, although of silver bromide composition, is of a type entirely different from all other photographic emulsions, making use of the solarization effect for the first time in practical photography. Some commercial possibilities of the new type of emulsion are seen in the duplication of x-ray and other valuable transparency originals, aerial mapping, motion picture still picture printing, photo reproduction practice, and general commercial photography.*

This paper, although concerned in one respect with motion picture film only as used for miniature photography, is submitted because it deals with the practical photographic use of the phenomenon of solarization. The process is new, interesting, even surprising, and it is felt that it holds great promise in respect to simplifying greatly the photographic process in general.

Let us start with the characteristic density-log exposure curve as shown in Fig. 1 for an ordinary photographic silver halide emulsion normally exposed in a sensitometer and developed in some common photographic developer, such as metol-hydroquinone-sodium carbonate and fixed in regular hypo. Only the parts A, B, and C, known respectively as the toe, straight-line portion, and shoulder of the curve, have been of practical importance for the regular negative, positive, or reversible emulsion; while the portions M and especially S are undesirable in any emulsion, because the registration of the light values in this part of the characteristic curve is distorted. The emulsion of the direct duplicating film now makes practical use of the part S, or the solarization portion of the characteristic curve. The effect here of exposure is exactly the reverse of the effect in the

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*Presented at the Spring, 1936, Meeting at Chicago, Ill.

** Agfa Ansco Corp., Binghamton, N. Y.

A, *B*, *C* portion. Before the maximum density *M* is reached, the density of the developed silver image increases with increase of exposure. Within the solarization range the density decreases with increase of exposure, or, in other words, a print, made from an original negative using only the solarization region, will be a negative, and a print from an original positive will be a positive—in either case, therefore, a duplicate of the original. Fig. 2 shows practical results attained[1] with an emulsion of this kind. For the left-hand picture an ordinary negative film was exposed in the camera; for the right, the direct duplicating film. The difference in exposure is indicated beneath the illustrations. The pictures were developed together in the same developer and fixed together in the same fixer. Applying

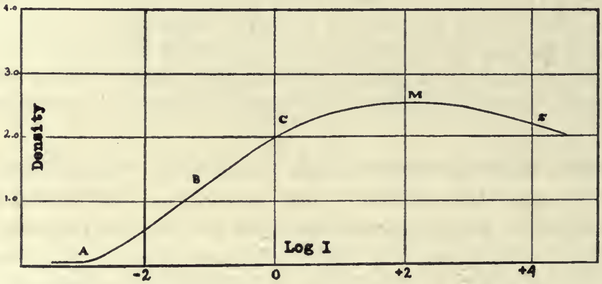

FIG. 1. Characteristic curve taken from the time-intensity-density surface of the extra-rapid plate.[1]

the same technic we get in one case the usual negative, in the other a duplicate. This duplicate is the exact replica of the original obtained in a single step, namely, a negative from a negative and a positive from a positive, as differing from the ordinary methods, which reverse the character by turning a negative into a positive or a positive into a negative.

There are other processes in photography that transfer the detail of a subject or picture to a film without reversing its light and shade values or, in other words, which produce a duplicate in a single step. Two may be mentioned here which do not employ a silver bromide emulsion. Bichromate gelatin is sensitive to light and is hardened by exposure. When the resulting gelatin relief obtained after the exposure is treated with a dye solution, the unexposed parts are colored, while the exposed parts, because of the hardening effect

during the exposure, remain colorless, and thus a duplicate dye picture is obtained.

Certain diazo compounds when struck by light are decomposed and become incapable of forming an azo dye. Unexposed parts of a diazo paper (such as Ozalide) when treated with ammonia, form a dye, *i. e.*, a density, while the exposed parts remain clear. The result is likewise a duplicate of the original.

Then there is the commonly known chemical reversal process used for processing amateur motion picture film. The emulsion is of about the same type as the ordinary positive or negative emulsion, and the toe, straight-line portion, and shoulder of the sensitometric

Super-plane-filmpack (*f*/11; 1/50 sec.) 3½ min. — Rollfilm developer — Direct duplicating film (*f*/4.5; 10 sec.) 3 min.

FIG. 2. A negative at the right, a positive at the left, although the two films, after being exposed in the camera, have been developed and fixed together in the same solutions.

curve are the essential parts here as in the regular positive and negative film developing process. The reversal effect is produced in this case by a bleach, second exposure, and second development, all after the original or first development.

The principle used in the direct duplicating film fortunately differs from all these. On account of its being a silver halide emulsion, the resulting picture is a silver image; but, unlike the reversible emulsion, it can be exposed, developed, and fixed similarly to all familiar photographic materials of silver halide type.

There are occasions in practical photography when, by accident, a partial duplicate results from very great overexposure of an ordinary emulsion. To produce the solarization effect intentionally, one would have to choose the emulsion carefully because there are

great differences in solarization. Some emulsions show greater susceptibility to solarization, and some show hardly any. Further, one would have to expose the emulsion up to the point M (Fig. 1) of maximum density, a procedure that is not very practicable. But in almost all cases it turns out that the characteristic curve is not sufficient for practical use, because the film does not show sufficient clearness and also because the density range of the solarization is not sufficient. All these difficulties have been overcome by the direct duplicating film. No preliminary exposure is necessary, but,

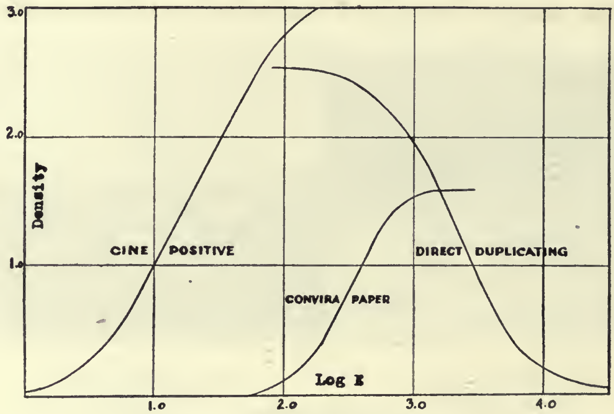

FIG. 3. Characteristic curves:

Film	Development Time	Developer
Positive 35-mm.	4 min.	Positive
Convira paper	2	Paper
Direct duplicating	6	Direct duplicating

so to speak, has been included in making the emulsion. Furthermore, the photographic qualities of clearness, gradation, *etc.*, are such that the direct duplicating emulsion is of real practical value.

The method of making this emulsion[2] is based upon the idea of replacing a preliminary exposure by a special ripening process. In the first place, a normal photographic emulsion having a very pronounced solarization is chosen. The emulsion is brought up to the point M, where the solarization range S begins, not by preliminary exposure, but by a special ripening in the presence of substances that cause fog. For instance, with an addition of silver nitrate or of photographic ripening substances, or of developing agents such as hydroquinone, the emulsion is treated at a high temperature for

a certain length of time. Later the surplus of the fog-producing agents is washed out. Not all emulsions give the same good result, but it can be said that all emulsions that show suitable solarization show at least a good solarization curve when ripened in the presence of fog-causing agents.

Fig. 3 shows the sensitometric curve of the solarized emulsion made in the manner described and used for the direct duplicating film. Of course, to achieve this result the original emulsion must

TABLE I

Some Data on Direct Duplicating Film with Various Developers

Developer	Development Time (Minutes)	Density Max.	Density Min.	Gamma	Latitude 2^n n
Direct duplicating	4	1.9	0.06	−1.5	
	6	2.5	0.08	−2.3	6
	8	2.7	0.10	−2.7	
X-ray	$3^1/_2$	2.2	0.08	−2.0	
	5	2.6	0.10	−2.5	6
	8	2.7	0.12	−3.0	
Glycin	8	1.8	0.12	−1.3	
	12	2.4	0.15	−1.7	6.5
	20	2.7	0.25 Y	−2.2	
Borax fine-grain	8	1.1	0.10	−0.6	
	12	1.6	0.12	−0.8	7.5
	20	2.0	0.18	−1.1	
Amidol	4	1.5	0.15	−1.3	
	6	2.2	0.20	−1.7	6 5
	10	2.4	0.25 Y	−2.0	

show pronounced solarization, and the most favorable conditions for the special ripening process must be determined experimentally. The range of density of the emulsion used in making the direct duplicating film is greater than 2.0 under suitable development, with a maximum density of about 2.5 and a minimum density (fog) of 0.1. The range of exposure covered by this curve is ample to produce photographically valuable results.

From Fig. 3 it can be seen that the general speed of the direct duplicating film is slightly less than that of the average contact printing paper. The speed is considerably less than that of motion picture positive film, a fact that makes the direct duplicating film

not quite suitable as yet for duplicating purposes in the motion picture industry.

Considerable experimenting has been done with various developers for the direct duplicating film. Table I shows some of the more

TABLE II

Developers Listed in Table I

Developer	Composition		
Direct duplicating	Metol	5	grams
	Sodium sulfite (anhydrous)	35	grams
	Hydroquinone	3	grams
	Sodium carbonate (mono)	30	grams
	Potassium bromide	1	gram
	Water	1000	cc.
(*To be diluted with 1 part of water; development time, 6 minutes at 65°*)			
X-ray	A metol-hydroquinone-sodium carbonate developer with		
	Metol	3.5	grams
	Hydroquinone	9.0	grams
	Water	1000	cc.
Glycin	Glycin	50	grams
	Sodium sulfite (anhydrous)	125	grams
	Potassium carbonate	250	grams
	Water	5000	cc.
Borax fine-grain	Metol	1.5	grams
	Sodium sulfite (anhydrous)	80.0	grams
	Hydroquinone	3.0	grams
	Borax	3.0	grams
	Potassium bromide	0.5	gram
	Water	1000	cc.
Amidol	Amidol	20	grams
	Sodium sulfite (anhydrous)	100	grams
	Water	5000	cc.

important results, while Table II describes the developers used to attain them.

As indicated by the maximum densities listed in Table I, the metol-hydroquinone-carbonate developers, such as direct duplicating or x-ray film developer, give densities higher than 2.5 in normal developing time. The glycin developer also reaches densities of 2.5, although the rather long development time required appears to be an inconvenience for practical use. Soft working developers, like

the borax fine-grain developer, give a lower maximum density. Their advantage lies in the flatter gradation and in the longer scale. Amidol developer renders a maximum density of 2.5, which is remarkable when it is considered that this developer contains no alkali.

All developers produce an increase in fog with an increase in development time, but metol-hydroquinone-carbonate developers give the best clearness with a fog of 0.08 to 0.12. Slower developers show a higher fog; for instance, the borax developer produces a fog of almost 0.2 before a density of 2.0 is attained, while the more rapid developers give maximum density before this fog value is reached.

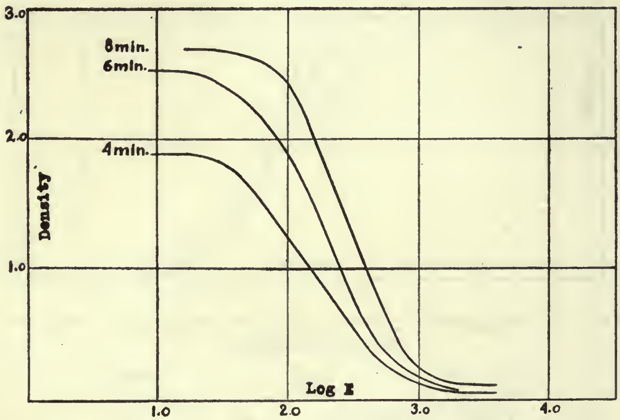

FIG. 4. Characteristic curves of direct duplicating film, developed in direct duplicating film developer for 4, 6, and 8 minutes at 65°.

In regard to the increase of fog with increased development time, the exposed silver halide grain of the direct duplicating film acts in the same way as the unexposed grain of the ordinary emulsion. However, in the case of the direct duplicating film the higher fog is sometimes accompanied by a slight yellow stain, as indicated by Y in Table I.

The gradation changes with the development time in the same manner as for ordinary film. Fig. 4 shows the increase of gamma as the development time is increased from 4 to 8 minutes.

All gamma values are indicated as minus, following the geometrical definition of gamma as the tangent of the angle between the straight-line portion of the curve and the abscissa. So this distinction is

made between positive gamma, indicating increasing density with increasing exposure, and negative gamma, indicating decreasing density with increasing exposure.

The gamma value of about -2.0 to -2.5 for normal development time indicates that the direct duplicating film emulsion has a contrast nearly the same as that of motion picture positive film (see Fig. 3).

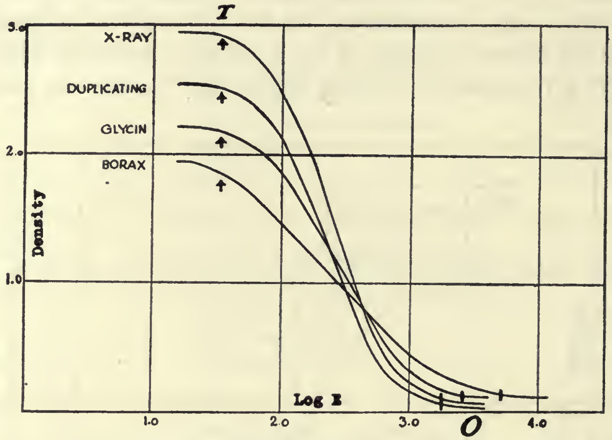

FIG. 5. Sensitometric curves of direct duplicating film for various developers:

Developer	Minutes
X-ray	5
Direct duplicating	6
Glycin	12
Borax	20

The curve for amidol developer, 8 minutes, is practically identical to the curve for glycin, except for the higher fog of 0.2, instead of 0.15 for glycin.

With the borax fine-grain developer, however, a gamma as low as -1.0 may be obtained (Table I).

In Fig. 5 the sensitometric curves of various developers are shown. The threshold speed, indicated at T, is the same for all developers. There are considerable differences in the gradation, such as -1.1 for borax developer and -3.1 for x-ray developer. The ranges of exposure, registered by differences in density, differ as indicated by the distances along the abscissa from points T to points O. For the borax developer, this range is about $2^{7.5}$, whereas for x-ray developer it is only 2^6. These illustrations show that the direct duplicating emulsion has characteristics similar to those of the

normal types of emulsion: for instance, increase of gamma and fog with increasing development time.

Besides these facts, which are of practical value, there are other properties of the emulsion that are more or less of theoretical value, two of which may be mentioned here. It is known that silver bromide emulsion, when immersed in a solution of methylene blue before development, shows quite an increase in fog. The same effect takes place with direct duplicating film (see Fig. 6). The maximum density in this case is only slightly less, while the fog increases considerably. Also the gradation becomes flatter.

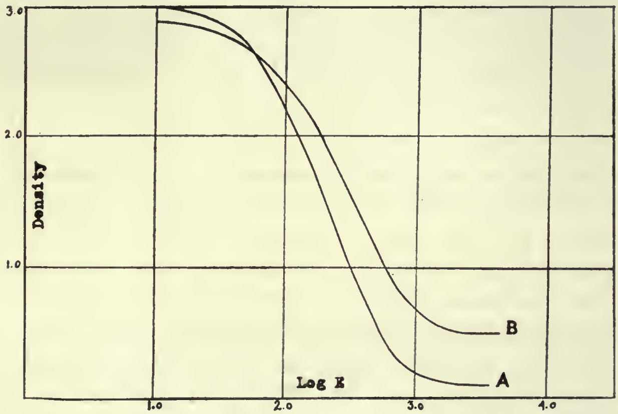

FIG. 6. Influence of methylene blue treatment: (*B*) film immersed in solution of 0.01 per cent methylene blue in water, and developed in x-ray developer; (*A*) film not treated with methylene blue solution.

Another interesting fact is the influence of physical development upon direct duplicating film (fixation before development). It is known that most ordinary photographic emulsions can be developed by physical development. The picture thus obtained is of the same type as the picture obtained after chemical development, but the range of density is much less and a physically developed picture generally has considerable fog.

Direct duplicating film was treated after fixation by physical development in the following way: The same negative was printed upon two sheets of direct duplicating film, the exposure being the same for both. One sheet was developed chemically in direct duplicating developer; the other, directly after fixing the exposure, in a

20 per cent sodium thiosulfite solution. The latter was washed very carefully, dried, and subsequently developed in a paraphenylene diamine silver nitrate developer recommended by Lumière and Seyewetz.[3] The development time was 20 to 40 minutes. After final washing and drying, the result was the positive shown in Fig. 7. The density range of this positive is about 0.7, with a fog of about 0.4 and a maximum density of about 1.1.

The result is remarkable in two respects: The exposure was the same for both the physically and the chemically developed films; the chemically developed film is a duplicate. The physically developed film is a negative of the original.

The surprising results achieved with this film might be discussed as they relate to various photographic theories. However, as the work is still in the experimental stage, and as new, interesting, and more complete results are expected to follow, it would be inopportune to go into such details at this time.

From the standpoint of further expansion of photographic theory it can be seen that the direct duplicating emulsion has great interest and promise. But the film is expected to find a place also in the field of practical photography. In general, the direct duplicating film can be used when duplicates are to be made of still pictures; for example, for making duplicates of portraits, commercial pictures, x-rays,* and in aerial photography. Making such duplicates requires only a single step and the film is handled just as is contact printing paper.

Another field projected for the direct duplicating film is in miniature photography, as has been pointed out by Rahts.[4] Miniature camera users have often regretted the difficulty of retouching their negatives, which can be accomplished only by making enlarged positives from which is made the contact negative for retouching. This lengthy double-step procedure is often detrimental to the pictures.

The reversible Leica film was introduced to help solve this problem as, instead of negatives, the user had a miniature positive which could be enlarged directly to a negative in one step. However, the disadvantage encountered in the use of such film is that, once used, two steps are required for every positive enlargement. By

* The direct duplicating film is now available for making duplicates of x-ray originals. It is coated upon the same blue-tinted base as used at present for normal x-ray film.

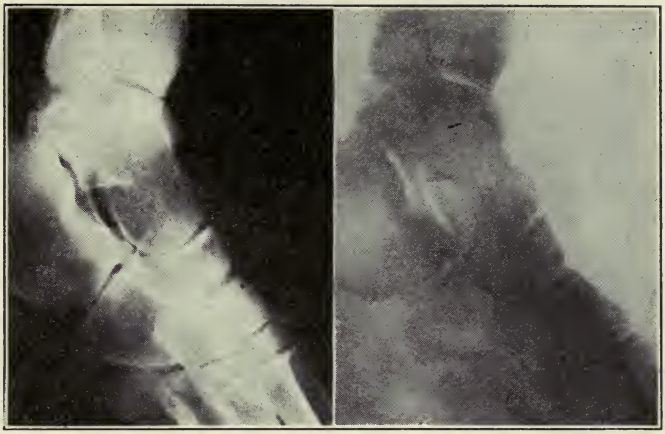

FIG. 7. Two films exposed for the same time under the same x-ray negative: (*Left*) film developed in direct duplicating developer and then fixed, resulting in a duplicate; (*right*) film, after same exposure, fixed and then developed in a physical developer, resulting in a negative.

FIG. 8. Direct duplicating film in miniature photography: (*Left*) unretouched enlargement; (*right*) enlarged positive obtained from enlarged partially retouched negative made in a single step with direct duplicating film.

using direct duplicating film with miniature negatives, only shots that need retouching require the double-step positive.

Here the direct duplicating film proves very useful. It provides the possibility of making from every original miniature negative an enlarged duplicate negative which may be used for retouching. The miniature negative is placed in the enlarger with the emulsion side facing the lamp. The emulsion side of the direct duplicating film faces the miniature negative. In this way the relative positions of the left and right sides are reproduced as in the original. The photographic characteristics of the direct duplicating film are flexible enough as to gradation to provide a satisfactory enlarged negative, and from this a satisfactory enlarged print. Fig. 8 shows one print made directly from the miniature original, compared with another print made from an enlarged negative on direct duplicating film.

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DISCUSSION

MR. GREENE: Is this emulsion adaptable to the methods of reproduction used by advertising agencies?

MR. SCHOECK: It is much too slow for camera work.

MR. TASKER: Why can it not be used for making motion picture duplicates?

MR. SCHOECK: Because of its speed, its low sensitivity. The sensitivity is below that of contact printing paper.

MR. TASKER: If we had enough time for making duplicates?

MR. SCHOECK: Given enough time, it will make direct reproductions.

MR. TASKER: Of good quality?

MR. SCHOECK: Well, it is still in the experimental stage. I should say it may tend to the hard side.

MR. MITCHELL: How does the grain size compare with that of ordinary duplicating positive stock?

MR. SCHOECK: About the same as that of direct duplicating emulsion.

THE BUSINESS SCREEN—SOME DEMANDS MADE BY AND UPON IT*

W. F. KRUSE**

Summary.—*Motion pictures have been used for advertising for a number of years, but only in the last few years has the use of the business film reached such outstanding proportions. The majority of such films are now shown on 16-mm. sound equipment.*

Some of the applications that have been made and the various groupings into which the several types of advertising pictures fall are described, including a brief historical explanation of why various types of films came into use.

The Committee on Non-Theatrical Equipment in its report deals in detail with general conditions common to all sections of the non-theatrical field. This paper is confined therefore to some specific problems confronting the section of the non-theatrical field which, for want of a better name, has come to be called the "Business Screen." Three questions stand out:

(*1*) What is the nature and scope of the "Business Screen"?
(*2*) What specific demands does it make upon the motion picture engineer?
(*3*) To what extent have these demands been met?

THE SCOPE OF THE BUSINESS SCREEN

A "business film" is, in essence, a sales tool. Its function is to tell a sales story to the potential consumer audience. Its sales appeal may be direct or indirect; it may be timed to tell its story in two minutes or two hours; it may have cost $100 to make or $100,000; it may be shown on a salesman's projector across a prospect's desk, or it may have gala presentations in the finest motion picture theaters rented for the occasion. Essentially its purpose is to *sell* the product offered by the film sponsor.

The universal popularity of the motion picture needs no proof. The fact that 80 per cent of the American public's amusement dollar goes for motion picture entertainment may be taken as conclusive

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* Presented at the Spring, 1936, Meeting at Chicago, Ill.

** Bell & Howell Company, Chicago, Ill.

evidence. The fact that thousands of progressive school teachers look upon the motion picture as a dynamic educator, and regard it as the most forceful interest-compeller in their entire arsenal of teaching tools, is corroborative.

For the business man, and particularly for the advertising and sales promotion executive, the motion picture quickly demonstrated itself as a unique, powerful medium to catch attention, hold interest, carry conviction, and impel favorable action toward the product or services presented by means of the film.

Advertising men are a canny lot. It is their business to know human thought-processes and how to influence them. They were among the first to recognize how "eye-minded" is the human race. From the earliest wood-cut illustrated advertisements, calling for the apprehension of runaway slaves, to the luscious, highly colored, double-page spreads offering automobiles, refrigerators, bananas, or shoe-laces, the advertising man has been far ahead of the Chinese sage who is supposed to have uttered the well known bromide that "one picture is worth more than 10,000 words."

No advertising man would be crazy enough to use 10,000 words, because nobody would read that many. The smart advertising man uses as many pictures and as few words as possible. The *smartest* use movies.

The advertising man is a keen student of psychology, both experimental and applied. He knows that a *light* is the first stimulus that can attract and hold the wandering eye of a very young human infant. If the light (or its embodiment in a brightly colored object) is set into *motion*, the attraction of the human eye toward this stimulus becomes irresistible. If sound is added, we complete the trinity of primary attention-getters—light, motion, and sound—which enjoy a virtual monopoly of sensory approach all through life.

The talking motion picture combines these three prime movers of the human mind in a degree that is not possessed by any other medium. The printed page uses the attractive power of light through white space and color, and attempts to simulate motion by printed speed lines, cartoon sequences, and successive motion picture stills—the highest compliment, attempted imitation of the motion picture. So prevalent has this tendency become that the Bell & Howell Company now makes a special "Candid Eye" camera to do this job. The radio uses only sound, and its groping in the direction of television is in itself a confession of a realization of its primary

shortcomings. The talking picture is the *only* medium that combines *all three* primary lodestones of attention—light, motion, and sound.

SOME USES AND RESULTS

The use of the business film has grown to an extent that is hardly realized even by the approximately 140 film-producing organizations directly catering to the needs of this section of the non-theatrical motion picture industry. A recent survey among 3000 business and similar agencies reported to be using 16-mm. motion pictures, revealed the data summarized in Table I.

TABLE I

16-Mm. Motion Pictures in 3000 Business and Similar Agencies

Circulation	Firms	Length of Picture	No. of Pictures	
Free	258	1-Reel	493	
Controlled	107	2-Reels	199	
Free and Controlled	41	More than 2 Reels	155	
Rented and Sold	23		847	silent 531 sound 316
	429			

Films per Firm	Firms
1	253
2	69
3	49
4	20
5	10
More than 5	28

Some results reported by devotees of the "business screen" will probably be of interest. A large steamship line reported that 3379 showings of its films reached 975,000 persons. An automobile manufacturer topped this attendance record by showing a baseball film to two million persons in a year.

In some lines specialized coverage means more than mass attendance. A pharmaceutical house set out to "detail" 107,884 members of the medical and allied professions; at the end of a year they had reached 105,873—98 per cent of the quota. By spending \$67,232.93, all told, on a film program, they did their job at $62^1/_2$¢ per head; other-than-film methods had previously cost \$2.13 per head for the same job.

An anti-freeze manufacturer spent \$18,500 for a direct-sales film,

and sold $600,000 worth of his product at net prices at shows arranged by his dealers and jobbers. A motor manufacturer spent $5000 for a film, featuring an item selling at only $70—but added 11 per cent to his profits on that item alone—besides the indirect benefits of general advertising and dealer recognition.

An oil company spent $25,000 for its first film—a 2-reel comedy on sales training. Upon carefully watching reports before and after introduction of the new advertising medium, they found that sales jumped by a general average of 16 per cent following film exploitation. Their next program called for $100,000.

WHAT MAKES A GOOD FILM GOOD?

To get good results, it takes a good film—well made, properly shown, and well adapted to its purpose. The question of quality is a difficult one to discuss. It is just as hard to say what makes a "good" business film as it is to say what makes a good cigar. Too many factors enter into the question. The tobacco itself, the blending, the workmanship, packing, and merchandising, all play their part. But in the last analysis, a lot depends upon the smoker—and upon "audience." The smoker's own preference and "technic," and the extent to which he "harmonizes" with those around him, all contribute to a composite idea of what makes a "good" or "bad" cigar. Similarly with pictures; the product to be presented, the way the story is prepared, the showmanship routine worked out to bring it to its audience, the effectiveness with which the sponsor's story is told in terms that will be favorably received by its audience, all must be considered in judging the quality of a film.

Our survey indicates also that in most business films direct advertising is kept at a minimum. There are exceptions, certain films made specifically as direct advertising media. A few pictures are as direct in their invitation to buy as a department store advertisement in a daily newspaper; and a considerable number of pictures, growing in importance, are devoted solely to teaching salesmen how to sell.

There have been business films almost since the birth of the motion picture. Some producers boast of more than 20 years of continuous production of industrial films. But it is a far cry from the early "factory run-arounds" and "good-will" productions to the smart, fast-moving, subtly dramatized sales "punch" that goes by the name of "business film" today. The modern producer of industrial films has a staff comparable to those of theatrical studios in ability,

imagination, and often downright genius. His job is really much harder: whereas the studio men strive solely to pick an appealing story and dish it out in a way they hope the public will like, the industrial producer must take the other fellow's story of cheese or pig-iron, and dress it up in such a way that the public not only will like it, but will spend their money, not for the film, but for the product plugged by the film. Otherwise, no more pictures—and all too many firms have had *only one* picture made.

CHANGES INTRODUCED BY 16-MM. FILM

The advent of 16-mm. sound films had far-reaching effects upon the business film. Hitherto the film advertiser had been limited to the theater, or to portable non-theatrical set-ups that were generally even more cumbersome to arrange. After his film was made, he was faced with the problem of dragging audiences into specially prepared places to see it, or else he resorted to "free-film" circulating agencies like the Y. M. C. A., or the U. S. Bureau of Mines, and the various State University extension centers. In the theater the advertising film was looked upon as an interloper; in the "free" field circulation was uncontrolled and was sometimes denounced even by some of the very users (teachers) for whom it had been so hopefully designed.

The 16-mm. sound film, like its silent predecessor, made it no longer necessary to drag the audience to the film; instead, the film could go out to the audience. With this change an important reorientation began to take place as to the content and tone of commercial films, and equally so as to their methods of exploitation. The film sponsor henceforth could control entirely in his own organization the use to which his film production was put, and he was able more accurately to check the results attained. He no longer had to camouflage his interest in his own film; he could speak of his product as frankly as he pleased, provided he did so in a way that would nevertheless keep his story interesting to the people to whom he expected to show it. Thus, refrigerator manufacturers talk of microbes, automobile makers preach safety, loan agencies extol budgets, department stores teach care of children and the educational value of toys, lumber dealers stress termite protection—but all really sell their product in terms of customer interest. The film user's own representatives now carry their whole show in their own two hands, right into the club, school, church, or home where his prospects are gathered.

SPECIAL FILMS FOR SPECIAL JOBS

The experienced commercial film user now discriminates as to the kind of film to use for certain jobs. Thus a certain motor-car manufacturer carried out a masterpiece of general advertising in his one-reel safety film, *Everybody's Business*, in which the name of the car was hardly mentioned, but in which the product was ever legitimately to the fore. The film was run in theaters, schools, police courts, department stores, by motor clubs, by the Red Cross, and numberless other organizations. This was one of the few advertising films ever made of which prints were paid for by outsiders who used the picture without the slightest alteration.

But the same firm uses several other types of films also—different types to do different jobs. They train their dealers and salesmen with direct sales-training films, and some of them are certainly "knock-down-and-drag-out" concentrated high-pressure sales dope. And they also have thrill films, and newsreels, and even a modernized version of the factory "run-around"—but planned for special schoolroom use, and for the mechanically inclined buyer; and maybe a bit as defense mechanism against competitors' factory films, the urge to show one's own plant as the "most stupendous and colossal" of all time. The well known Hollywood "cycle" disease is infectious also among the industrial film users, but more prevalent is the healthier demand that each picture be "different" from anything ever done before by anybody.

One other case: a manufacturer of spark-plugs entered the field with five different films for as many different jobs:

(*1*) A "run-around" to glorify the spark-plug in general, and their own in particular.

(*2*) A fine entertainment film of racing thrills and spills for the casual club or county-fair audience.

(*3*) A technical animated film showing the function of the spark-plug and the reasons for the particular designs, intended mainly for showing to auto mechanics, classes in high school, *etc.*, to the mechanically inclined, and to their dealers as technical sales ammunition.

(*4*) A newsreel showing a helicopter equipped with their plugs, flying over the Maya ruins. This was used when needed to tone down the sales angle.

(*5*) A sales training film showing the salesman how to achieve a 100 per cent average on new plug sales, dramatized in service-station and garage settings, with half a dozen crusty customer skeptics converted (in the film).

In addition to making their films as "entertaining" as possible, par-

ticularly those intended as a sugar-coated approach in a direct consumer sales drive, many users of industrial films supplement their own productions with rented entertainment film, thus rounding out the program.

ENTERTAINMENT AND COÖPERATIVE PICTURES

Most industrialists wish to change their entertainment films frequently, so they avail themselves of the existing sound-film rental library facilities. Others, with long-range programs, buy outright such entertainment or educational films of high quality as they regard timely and suitable, and, in fact, advertise them as part of their own shows.

Another interesting development is the tendency to make a single picture for a group of manufacturers, each of whom has an important and non-competitive part in the total product being demonstrated. A single film will be used by the motor manufacturer, the tire maker, and by purveyors of various incidental parts such as sparkplugs, piston rings, roller bearings, gasoline, lubricants, paints, and other incidental products. Another variant of this tendency is for a manufacturer of an essential part to make a film dealing solely with his contribution, this film to be inserted into a larger industrial picture already produced, by the vendor of the composite product.

DEMANDS TO BE MET

The money spent on the business screen by large manufacturers comes back considerably multiplied, in the form of additional profits. But this profit is realized only if the exploitation of the film is kept in mind at every step of the planning and production. To get any good out of a picture program, the film has to be *shown* to its audience just as finely as possible. Audiences today compare the business screen presentations with what they have come to be accustomed to in the theater. This places a serious problem before the equipment manufacturer and the motion picture engineer who designs the equipment. The average purchasing agent for a film sponsor wants to buy a sound projector powerful enough to show brilliant, flickerless, evenly illuminated pictures to an audience of 5000 and up, perfectly reproduced sound that can be heard half a mile, self-threading, self-operating, self-oiling, fitting into a small brief case, weighing perhaps two pounds, and costing maybe ten dollars.

The motion picture industry has not had these specifications very long, but we have all done what we could to meet them.

A few examples: With a 1000-watt projector 16-mm. film has been used in auditoriums seating 3500. Users have reported that a 750-watt machine is satisfactory for indoor audiences of 1800 and of 2500, and for outdoor audiences of several thousand.

It is possible to equalize the screen illumination over the entire screen area with a difference of less than 20 per cent between any two points chosen anywhere on the screen. It is possible to achieve steadiness of the screen image within a tolerance of 1/300th of the linear screen dimension, *i. e.*, a movement of less than $^1/_4$ inch on a 6-ft. projected image.

It is possible to get 16-mm. sound amplifiers with a 25-watt output, undistorted within $2^1/_2$ per cent. It is possible for the sound projector to reproduce a greater frequency range than has thus far been printable on 16-mm. film. The present response range (40 to 10,000 cps.) is adequate for any advertising purpose, and the fact that 16-mm. reproducers are used for teaching and demonstrating piano and violin is sufficient tribute to their excellence. Improvements in the laboratory process already perfected will further increase the fidelity and range of 16-mm. reproductions.

Threading and operating has been simplified to such a degree that a large battery of machines *can* be placed in the hands of utterly untrained operators and run satisfactorily with no other guidance than the instruction book faithfully used. Furthermore, these same machines can be packed by their amateur users, shipped to another, and another, similarly untrained operator, and good results repeated. Needless to say, such a procedure is not ideal, and the more thorough the instruction of the operator the better will be the results.

As to weight, size, and cost, unfortunately thus far these factors have remained largely proportionate to the sound and screen lumen output. As differentiation proceeded in respect to the work to be done by equipment assigned to different types of jobs, so there has grown a differentiation in the size, weight, and cost of equipment designed to do these various jobs. The present range of available models, from auditorium projector to a single suit-case model that slips beneath a Pullman berth, indicates that the same differentiation of function that governs in the automobile industry will probably be paralleled, especially as motion picture projectors more and more become articles of mass consumption.

Another demand put to the engineer by the movie-using industrialist is for a low-cost 16-mm. sound recorder. There have been some interesting developments in this field, and the trend is viewed with grave misgivings by professional producers of industrial sound films. We had a similar situation when the 16-mm. silent camera first made its appearance, yet the net result was that hundreds of new firms entered the ranks of movie users, and producers turned out more films rather than fewer as a result of the "roll your own" film movement.

The motion picture engineer has tried so hard to meet the demands of the "business screen" that he may be pardoned if he puts a few demands of his own to the users of business films. He should urge the abandonment of the idea that it is good business to expect something for nothing. He should urge that every commercial use that is made of the motion picture be really worthy of the medium. He should insist that motion pictures really move, and that talking pictures really talk. Productions should be adequate, equipment and exploitation programs likewise. He should point out to the uninitiated the folly of trying to present a two-hour film to a two-minute audience, and, *vice-versa*, a two-hour story in a two-minute film. He should preach tirelessly the gospel that whatever is worth doing at all is worth doing well. We are keenly alive to the uses to which our products are put, for upon successful and constructive use of our product depends the future of our industry.

NEW MOTION PICTURE APPARATUS

During the Conventions of the Society, symposiums on new motion picture apparatus are held, in which various manufacturers of equipment describe and demonstrate their new products and developments. Some of this equipment is described in the following pages; the remainder will be published in subsequent issues of the Journal.

1000-WATT 16-MM. FILMOSOUND PROJECTOR*

R. F. MITCHELL AND W. L. HERD**

The Filmosound 16-mm. sound-film projector is of advanced design, incorporating many unusual features, such as a 1000-watt lamp and *T-12* bulb, motor drive take-up and motor rewind, built-in film humidifier, and many other features. It is being used to show 16-mm. sound pictures to audiences up to 4000 persons (in the auditorium of the National Geographic Society). This is, perhaps, the limit of its capacity; normally it is entirely adequate for an audience of 1000. Despite its power, the complete projector, amplifier, loud speaker, cables, and film for a complete show, all go into two cases, one weighing about 50 pounds and the other about 35, constituting an outfit that is readily portable in an ordinary car. The advantage of this for lecturers who must travel from place to place and talk to audiences of various sizes is evident.

Fig. 1 shows the arrangement of the equipment in its two cases. Figs. 2, 3 and 4 show the essential features of the projectors and amplifier units. The projector consists mainly of die-castings. The intermittent movement is similar to that of the well known *Filmo* projector, being of the harmonic cam type and employing a single-bladed shutter with an unusually large open segment of 216 degrees. The shutter rotates three times for each frame that is projected, thus giving two intermittent flicks in the picture upon the screen. Due to this design, steady and flickerless pictures are readily obtained. The normal screen width recommended is about 10 or 12 feet.

While the projector was being designed, the lamp manufacturers were requested to develop a 1000-watt projection lamp using a *T-12* bulb. It was realized that especially efficient ventilation would be required to permit such a lamp to be used satisfactorily. Accordingly, especial attention was given to the fan and ventilating system of the projector. The 1000-watt lamp in a *T-12* bulb, with the efficient ventilation provided, easily gives its rated life of 25 hours. The main advantage is that the arrangement permits the use of short coupled optics, thus utilizing the maximum amount of light from the lamp. Accordingly, the optical efficiency of the projector is quite high.

As will be seen in the illustrations, the projector is supplied with reel arms large

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* Presented at the Spring, 1936, Meeting at Chicago, Ill.

** Bell & Howell Co., Chicago, Ill.

enough to accommodate 1600-ft. reels. A 1600-ft. reel of 16-mm. film is equivalent to a 4000-ft. reel of standard film. One threading of the machine is sufficient for a 50-minute show. The machine can also handle reels of smaller capacity, available in 1200-, 800-, 400-, and 100-ft. sizes.

The speed of the projector is controlled by a centrifugal type of vibrating-reed electric governor of extremely efficient design. Speed is guaranteed to be constant within 2 per cent, with line voltage variation from 100 to 125 volts. As a matter of fact, the governor will compensate for variations from 90 to 130 volts without noticeable change in the pitch of the reproduced sound. The governor is adjustable, having two pre-set positions permitting operation at speeds of

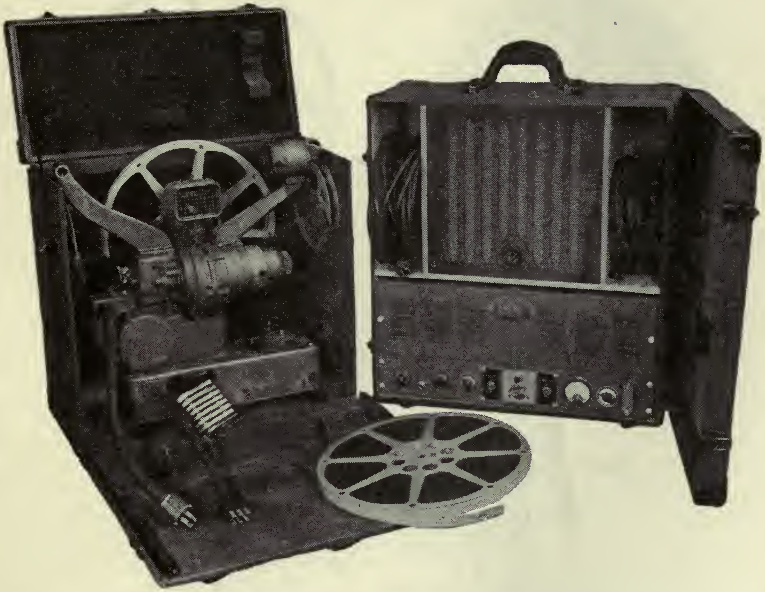

Fig. 1. 1000-watt 16-mm. Filmosound projector, with humidor unit removed to show arrangement.

16 and 24 frames per second. The regulation of the governor is so close that a heavy synchronous motor is not necessary, permitting the projector to be used interchangeably on 25-, 50-, and 60-cycle a-c. or d-c., which is an especially important feature for lecture or road show work.

An unusual feature is the use of a separate electric motor for the take-up. Because of the large variety of reel sizes that can be accommodated, and because of the range of speeds at which the projector will operate, it was found that the conventional types of drive were not sufficiently reliable. Accordingly, a separate take-up motor was designed, the speed of which is controlled by a calibrated rheostat. In conjunction with the take-up a shock-absorbing snubber has been incorporated which effectively prevents film damage due to inaccurate or bent reels, and is really simple in operation and works most efficiently.

Another unusual feature incorporated in the take-up motor is the provision of special windings permitting this motor to run at high speed in the reverse direction for power rewinding. A 1600-ft. reel is rewound in less than one minute. A fool-proof change-over switch, provided to switch the motor from take-up to rewind, is interlocked with the main switch so as to prevent accidentally switching on the take-up motor to rewind during projection. The machine must be turned off, the lever set for rewind, and then the main switch turned on again.

In order to reduce the danger of burning out lamps and to assure the most satisfactory operation under varying voltages, the lamp is connected in circuit

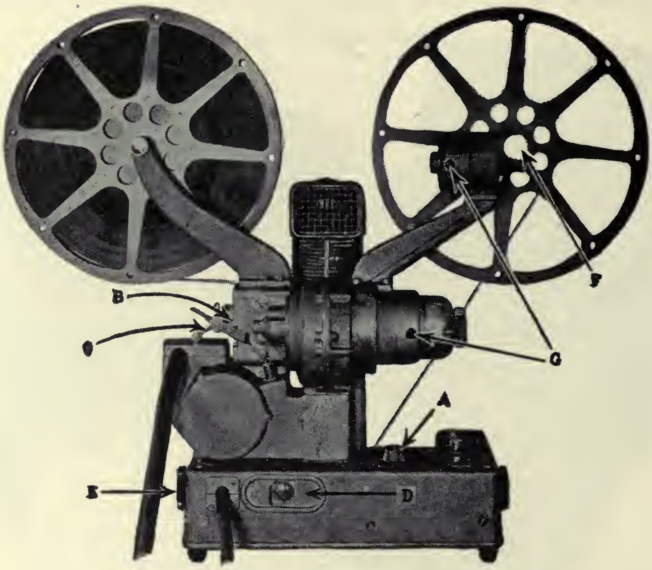

FIG. 2. 16-Mm. Filmosound projector:

(A) Take-up tension adjustment
(B) Hand setting knob
(C) Gate operating lever
(D) Humidifier
(E) Front titling knob
(F) Gear chamber
(G) Motor brush screws

with a variable rheostat located in the lamp house where it will be effectively cooled. A voltmeter shows the voltage across the lamp. When starting, the rheostat is turned all the way down, and is then brought up until the voltmeter registers correctly. The voltmeter is illuminated by a pilot lamp, the light from which is reflected to the voltmeter by a small polished metal stud to the front left of the voltmeter. The pilot light is shielded, and the shield can be rotated to direct the light to any part of the projector so that the pilot can be lighted during projection without annoying the spectators near the machine.

A unique feature has been incorporated in this machine—namely, an automatic humidifier. Although the cooling system was found entirely adequate to maintain correct operating temperature even when the projector was used in a warm room and with high voltage, it was felt desirable to incorporate a humidi-

fier to restore moisture to the film. This problem is more severe with 16-mm. projection than with theatrical work because 16-mm. film is made of acetate safety stock, which tends to lose and absorb moisture rather readily. The humidifier consists of a series of plates of absorbent material inserted into the back base of the machine. Moist air passes through a channel from the humidifier to a slot through which the film travels. This blast of moist air impinging upon the film immediately after projection has been found to add appreciably to the life of the film.

Incidentally, discussing film life, it may be of interest to mention that, in contrast to theatrical projection, in which three or four hundred projections represent

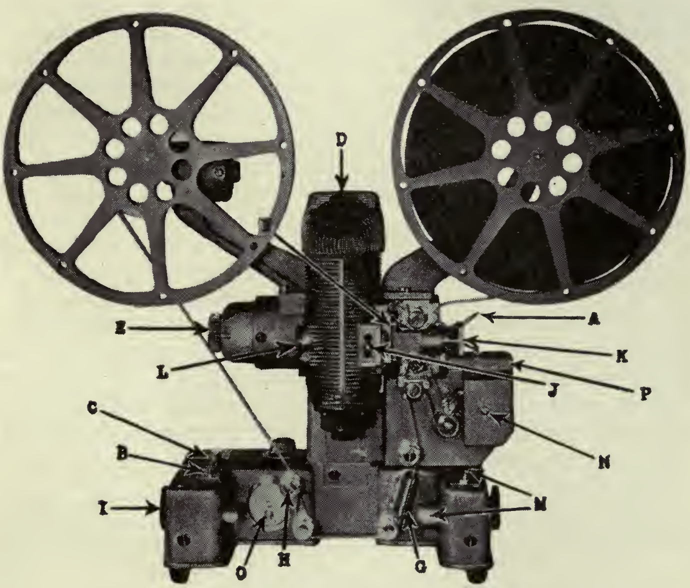

FIG. 3. 16-Mm. Filmosound projector:

(*A*) Motor clutch lever
(*B*) Current supply switch
(*C*) Rewind-run lever
(*D*) Lamp voltage control
(*E*) Motor speed adjustment
(*F*) Manual framer
(*G*) Humidifying slot
(*H*) Snubber
(*I*) Rear titling knob
(*J*) Condenser
(*K*) Projection lens
(*L*) Reflector
(*M*) Pilot light and switch
(*N*) Exciter lamp housing
(*O*) Voltmeter
(*P*) Sound head cover

good film life, it is now possible to project 16-mm. film more than 1000 times without appreciable deterioration. In fact, some tests have run to 16,000 projections.

For auditorium use, it is usually required that the projector be tilted down from the balcony or up from the main floor. Accordingly, tilt knobs have been provided at both front and back, which operate legs for tilting the projector upward or downward to an angle of about 10 or 15 degrees. The low, stream-line base is

important in this connection because it provides the necessary strength and low center of gravity that permits the projector to be tilted with perfect safety even when using the large 1600-ft. reels.

Sound System.—The projector is arranged to be used with the special amplifier shown in Fig. 4. A shielded cable carries the impulse from the photoelectric cell to the amplifier. Another cord carries the power to the projection lamp, motor, and exciter lamp, which are controlled at the amplifier. The line switch on the projector is left in the "on" position. When operating two projectors, one machine or the other is started with one of the two switches provided, depending upon which machine is being used.

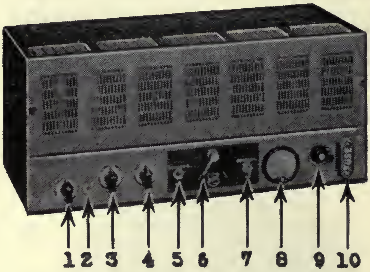

FIG. 4. Filmosound amplifier:
(*1*) Microphone volume control
(*2*) Microphone jack
(*3*) Tone control
(*4*) Film volume control
(*5*) No. 2 projector switch
(*6*) Change-over switch
(*7*) No. 1 projector switch
(*8*) Amplifier meter
(*9*) Amplifier line-switch
(*10*) Fuse box

The amplifier embodies all the necessary conveniences as well as several not found in ordinary theater-type amplifiers, made necessary because of the use made of the equipment and, more particularly, because of the relative inexperience of operators. For example, instead of supplying the usual type of voltmeter and instructing the operator to set the voltage input to the power transformer to a certain voltage, the voltmeter is supplied with a dial that is blank except for a red area within which the pointer is to be adjusted. A line switch is provided with several taps so that the operator merely turns it until the voltmeter needle falls within the red area. The extent of this area is ten volts.

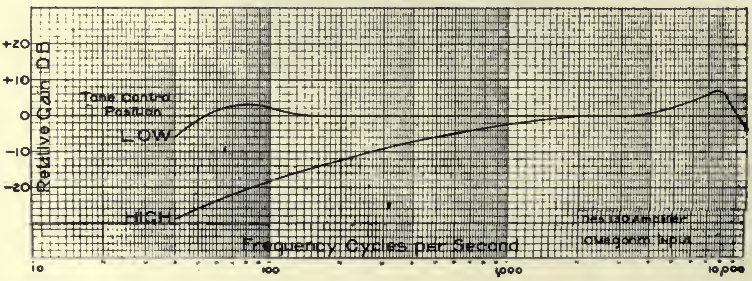

FIG. 5. Response curve of amplifier, showing range of tone control adjustment.

In addition to the conventional volume control, a separate volume control is provided for the microphone. This feature is used extensively for adding comments to films, and also permits the equipment to be used as a public address system. Because the equipment is intended for use in halls of various sizes and

acoustic properties, an extensive tone control is quite necessary for satisfactory operation. With it the operator can adjust the quality of the output to compensate, at least to some extent, for the variable acoustic properties of the auditoriums and for various characteristics of recordings.

The amplifier comprises four stages of amplification, terminating in a class *AB* power stage of four *45* tubes in parallel push-pull. The power stage is driven by a type *42* tube, employed as a triode and coupled to the output stage through a suitable transformer. The first stage of amplification consists of a *6C6* pentode resistively coupled to a *6C6* operating as a triode, Resistance coupling is employed

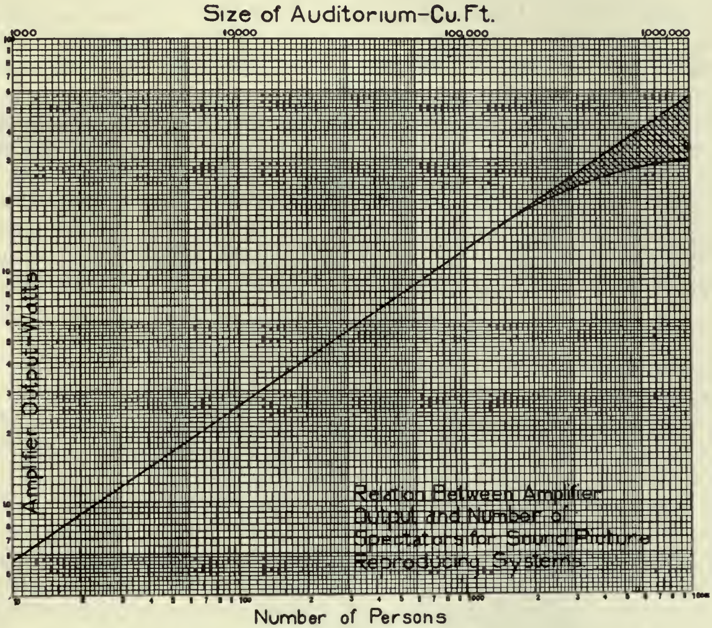

FIG. 6. Relation between amplifier output and number of spectators for sound-picture reproducing systems.

throughout, with the exception of the input and the output circuits of the power stage. Direct current is supplied by a mercury-vapor rectifier. A type *80* rectifier, complete with power supply and filter, is contained within the loud speaker case, and this design permits adequate field excitation for the speaker with no loss of regulation in the amplifier circuit. Careful design has resulted in a high-gain amplifier, which produces a surprisingly realistic output with a minimum of hum and distortion.

Fig. 5 shows the response curve with the tone control in the high and low positions, and indicates the range of control. The normal output of the amplifier is in excess of 25 watts, with a total harmonic distortion of less than 5 per cent. Momentary peaks in excess of 100 watts and without objectionable distortion have

been measured. Considerable difficulty was at first experienced in obtaining a single speaker of satisfactory size and weight that would stand up in actual service. The unit adopted is a Magnavox speaker made especially for the reproducer and possessing a rating of 25 watts in continuous operation. It is a 12-inch electrodynamic unit, mounted rigidly inside the carrying case. The speaker case carries the amplifier and connection cords, and is sufficiently large to constitute a satisfactory baffle without being cumbersome.

Care has been taken to provide all cords with non-interchangeable plugs so that incorrect connections are impossible, which is very important for all portable service.

The amplifier is of the conventional a-c. type. However, the user very often is forced to operate the equipment on direct current, so arrangements have been made to operate the projector motor and lamp on d-c., using only a small portable convertor for supplying a-c. to the amplifier.

For certain semi-permanent installations, it has been found desirable to supply more than one speaker. Auxiliary speakers are furnished complete with cases, power supply, and impedance-matching transformers. The circuits have been so arranged that additional speakers may be connected as required, and no thought need be given by the operator to matching impedances. Fig. 6 shows the relation between the size of auditorium and the power necessary to furnish adequate sound. Although the curve is empirical, it has proved a useful guide in practice.

DISCUSSION

CAPTAIN BRADLEY: How accurate is the rehumidifier?

MR. MITCHELL: We have no data that actually show how effective it is. It is largely relative, depending considerably upon the initial condition of the film and upon the conditions under which the film is projected. On a dry day it is very effective.

MR. KELLOGG: How was the original recording of this film made?

MR. MITCHELL: On 35-mm. At least 95 per cent of the commercial pictures are made that way, due to the difficulty of getting the highest sound quality directly on the 16-mm. negative. The investment in actors, lights, and so forth is so great that it is not very safe to make the original negative anything but 35-mm. There is a very decided and definite saving in making the print on 16-mm. The principal saving is in size and portability of equipment. We can get good results from equipment of this kind with audiences up to 4000 persons, even though that is stretching the capacity of the equipment considerably.

MR. KELLOGG: The sound is re-recorded from the 35-mm.?

MR. MITCHELL: Optically reduced, directly.

MR. GREENE: Were the response curves only transmission curves, or with the amplifiers?

MR. HERD: Transmission curves, amplified from the photocells, not including the rest.

KODASCOPE MODEL *E**

A. E. SCHUBERT AND H. C. WELLMAN**

The Kodascope model *E* was designed to provide optimal picture quality at a price that the average amateur can afford to pay. Heretofore, low-priced projectors have involved sacrifices as to quality, illumination, steadiness, flicker, definition, and mechanical noise. In the new projector it was decided that these fundamental qualities should be retained, but that some of the features that add materially to the cost and are not strictly essential might be omitted.

FIG. 1. Model *E* Kodascope.

* Presented at the Spring, 1936, Meeting at Chicago, Ill.

** Eastman Kodak Co., Rochester, N. Y.

The Kodascope *E* was the result (Fig. 1). It has neither still nor reverse, but mechanically and optically gives the maximum in performance and illumination. It is housed completely in aluminum die castings. The mechanism is rugged and extremely simple, and is designed to render satisfactory service for hundreds of hours. It has ground shafts throughout, and double bearings for all high-speed

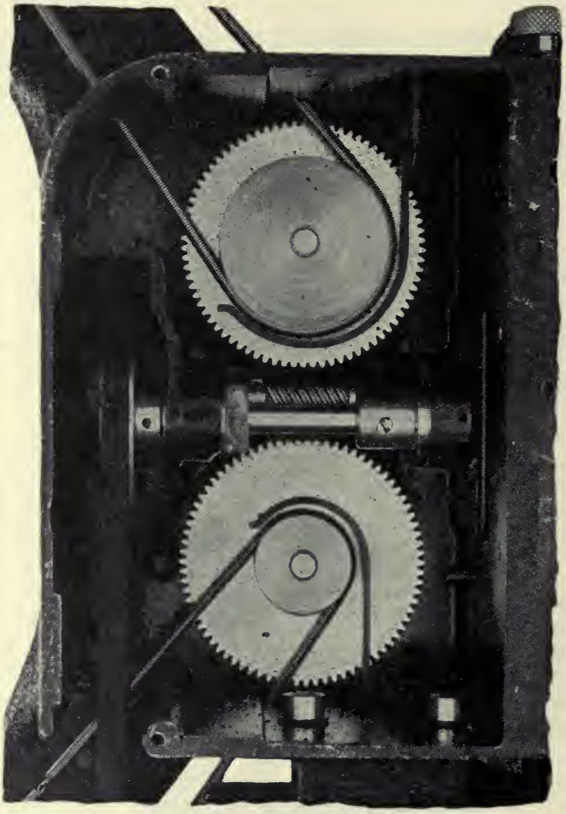

FIG. 2. Drive mechanism.

shafts to eliminate noise caused by wear. Gears are cut after the blanks are mounted upon the shafts, and each is checked for eccentricity of the pitch circle (Fig. 2). The maximum tolerance allowed in this respect is 0.0005 inch. Contacting points of the cam-operated intermittent claw are of hardened steel and phenolic composition, which eliminates metallic click from these fast-moving parts and minimizes wear. The pull-down claw is hardend at the wearing points, but straightness and flexibility are maintained by copper plating before hardening and by buffing away the plating only at the points at which wear might occur. A

three-bladed shutter, each blade of which covers an angle of 56 degrees, provides an open period of 192 degrees. Framing is accomplished by shifting the pull-down claw in relation to the aperture. After extensive research to test their worth, oil-impregnated bearings were adopted throughout, assuring permanent, positive lubrication. There are only two places to be oiled by the user of the machine, one for the pull-down claw and one for the main helical gear.

The lamp house and fan unit were designed particularly for high-wattage lamps. The very effective cooling provided results in long lamp life and maximum

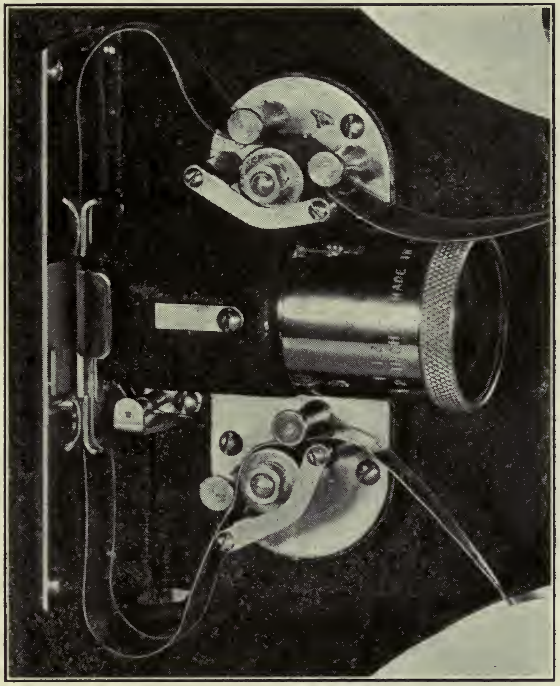

FIG. 3. Lens system and gate, showing film path.

illumination. The optical system was specially computed to provide adequate screen brilliance and picture quality, and although rigidly mounted, it is extremely accessible for cleaning. The lamp house top snaps into or out of position; the upper lamp baffle is removable; by removing the lamp, the condenser unit slips out for cleaning; and the reflector is equally accessible.

Threading is simple and conventional. The "out" position of the pull-down claw is indicated at the upper sprocket (Fig. 3). When any tooth of the sprocket is aligned to this mark, the claw is withdrawn from the gate and the film can be threaded without obstruction. Fixed film guides of hardened steel at the sprockets eliminate the necessity of opening frames or remembering to close them. Chro-

mium-plated relieved gates and aperture plates guard against wear and protect the film from being scratched or otherwise injured.

Rewinding is motor driven, simplified by a special patented reel spindle. After projecting a film, the take-up reel is merely moved into its free position, the rewind belt is placed upon the pulley, and the motor switched on.

The pedestal is of cast iron, to provide stability. The whole mechanism pivots upon the top of the base allowing a 30-degree tilt for aligning with the screen.

The model *E* will fulfill a wide range of projection requirements. While the 2-inch $f/2.5$ objective is standard equipment, the 2-inch $f/1.6$, the 1-inch $f/2.5$, the 3-inch $f/2.0$, and the 4-inch $f/2.5$ are available if desired. With these lenses, in combination with the 400-, 500-, or 750-watt lamps, it is possible to attain a maximum screen illumination of 210 lumens, a length of throw of 80 feet, and a picture $9^1/_2$ feet wide. The standard model is fitted for 400-ft. reels only. In conclusion, another feature may be mentioned. The base of the model *E* is made to fit down over the handle of the carrying case, which thus acts as a projection stand.

SYMPOSIUM ON THE SLIDE-FILM

Due to the considerable increase of interest in, and the use of, slide-film projectors of all sorts for educational and commercial purposes, a symposium on the subject was held at the Chicago Convention of the Society on April 30, 1936. Following are three of the papers presented in the symposium, and the joint discussion that followed two of them.

IMPROVEMENTS IN SLIDE-FILM PROJECTORS*

MARIE WITHAM**

In seeking the perfect complement to the motion film, we come to the younger but equally efficient slide-film—each performing a definite job. There has never been a doubt of the instructional value of still pictures, or slides, whether for educational or industrial purposes. In recent years the need for visual selling and visual instruction has steadily increased and with this demand has come a constant growth of the acceptance of the slide-film.

This medium is known by a multiplicity of names—still-films, strip-films, film-slides, and so on, but they all refer to a short strip of 35-mm. non-inflammable motion picture film upon which has been printed in sequence a series of photographs, charts, drawings, or titles. Two designations are now quite generally used: in the educational field such films are called *filmslides* (one word) or *Picturols;* and in the industrial field *slide-films;* the reason for the two designations being perhaps that in the educational field they take the place of the *glass* slide, hence *film* slide, while in the industrial field the difference lies in the minds of the users between *motion* films and *slide* films. It would be a distinct service to the trade if the SMPE would suggest one standard name as a general designation for such still films as are here under consideration.†

Equipment for projecting such films has been on the market for many years. The first standard *S. V. E.* film stereopticon was originally known as the "Arto." A few years after its aggressive distribution began, two of the largest optical concerns introduced similar equipment: first the Spencer Lens in 1925, and about a year later, the Bausch & Lomb slide-film projector. These were followed by slide-film attachments for use on standard glass slide projectors, which have not proved very convenient or satisfactory. However, new models designed to show slide-films only have been produced very rapidly during recent years, and it is with regard to this trend of advancement that we are especially interested.

In the development of motion picture equipment we have gone from little il-

* Presented at the Spring, 1936, Meeting at Chicago, Ill.

** Society for Visual Education, Inc., Chicago, Ill.

† The editorial style adopted is *slide-film.*

lumination to greater illumination, whereas the progress in slide-film projectors has been partially the reverse. The 200-watt Picturol projectors were in wide use in schools and industries when a demand came from industry for a small unit for use by contact salesmen for showing the pictures to very small groups of persons. The Society for Visual Education immediately developed the first of a series of very small 50-watt projectors, which, because of their efficiency and low cost, were widely adopted and utilized during all the years of the recent depression. The first and most interesting of these, perhaps, was the self-enclosed *S. V. E.* Jam Handy Pocketer, which actually slips into a man's pocket. The unit

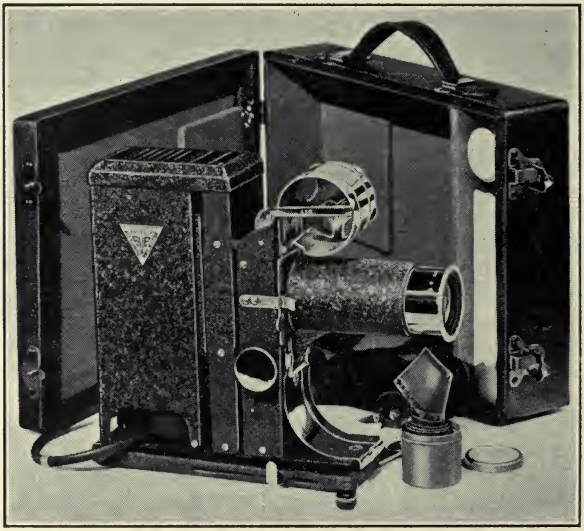

FIG. 1. Model *F* Picturol projector.

was original in design and size, and was the pioneer in utilizing the *T-8*, 50-watt, bayonet base projection lamp. This pocket projector served a definite need, and undoubtedly aided in establishing the demand for compactness and portability in projection equipment of this type. Subsequently, half a dozen other 50-watt models were added to the *S. V. E.* line, two of which, like the original, are also self-enclosed units.

The addition of sound to the slide-film permitted larger audiences to be served; with a consequent need for greater illumination, which has been generously supplied in the two latest models of single-frame film stereopticons—the *S. V. E.* Picturol projector model *F*, a 200-watt unit (Fig. 1), and the even newer Picturol projector model *Q* (Fig. 2), a 100-watt unit. As in all standard single-frame film stereopticons, the aperture is the same as that used for silent motion pictures. The model *F* presents some interesting details. Since no shutters are necessary in film stereopticons and because of its compact construction, the illumination of

the model *F* 200-watt projector compares favorably on the screen with 400- or 500-watt 16-mm. motion picture projectors (Fig. 1).

Optical systems used in film stereopticons are very similar to those utilized in motion picture projectors with the exception of the aperture plates and the all-important heat-absorbing heat-resisting element—without which slide-films can not be successfully used if the maximum illumination is to be obtained. Double aperture plates, which act as pressure plates to hold the film flat during projection, assure a sharp image over the entire screen and also tend to dissipate the heat.

The new model *F* 200-watt equipment is the first *manually* operated slide-film projector having a rear aperture glass releasing mechanism, a patented feature used exclusively for a number of years in the *S.V.E.* automatic projector de-

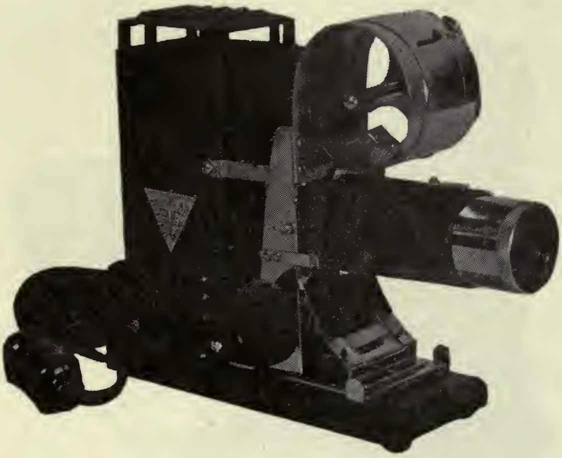

FIG. 2. Model *Q* Picturol projector.

signed for advertising purposes. The purpose of the releasing feature is to protect the emulsion side of the slide-film while it is being moved between the aperture glasses. The release operates in synchronism with the operating button by means of a cam that moves the rear aperture glass back instantly when the operating button is turned in either direction. The glass is held in a free position until a complete new frame is brought into position, and is then automatically returned to the normal projection position.

The new model *Q* projector embodies most of the important features of the model *F*, but has been designed to take care of smaller groups and therefore utilizes a 100-watt, *T-8*, bayonet base projection lamp; and, due to the location of the light-source with respect to the optical system, a remarkable amount of illumination has been obtained (Fig. 2).

In particular reference to the educational field, in which there has always been a comparison between the *glass* slide and the *film*-slide, it has seemed advisable to consider a picture projected from an area larger than that of the single-frame

35-mm. film. *S.V.E.* has therefore developed a new line of double-frame projectors to meet not only the need for better quality projection in the classrooms, but more particularly, the immediate requirements in the amateur field, in which the use of double-frame cameras, such as Retina, Leica, Contax, Super-Nettle—and the more recent Argus Candid Camera—is now rather extensive. These new *S.V.E.* combination projectors accommodate both single-frame and double-frame slide-films, and also project 2 × 2-inch glass slides, or individual slide-films of either size mounted between two pieces of 2 × 2-inch glass. They have been designed to provide greater ease of operation, a better distribution of illumination over the double-frame area, and to meet the demand for a more popular priced equipment than previously available. Some of the special features of these two new models are as follows: The model *AA* double-frame Picturol projector is

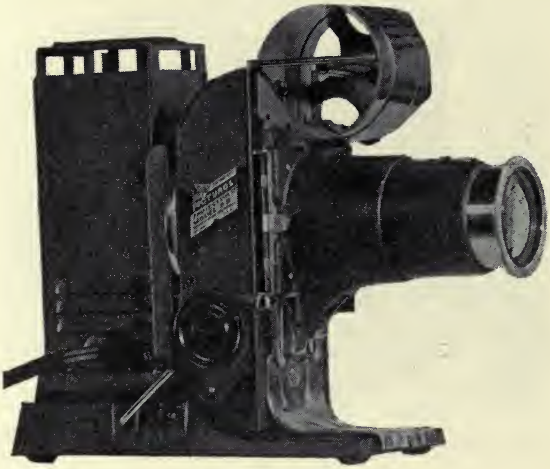

FIG. 3. Model *BB* Picturol projector.

equivalent in many ways to the model *F* previously described, and is also a 200-watt unit; while model *BB* (Fig. 3) is a 100-watt unit comparable to the model *Q*. Both are provided, however, with two masks, one being the standard single-frame aperture and the other a double-frame aperture. The masks are easily interchangeable, so that the projector is instantly adapted to take either the single-frame or the double-frame film (Fig. 3).

The head of the projector is of a swivel design so that it will show either horizontal or vertical pictures by merely turning the head of the projector to the appropriate position, and it is novel in that it may be swivelled either to the left *or* the right as occasion demands.

The two most important and entirely new features of the equipment are the framing and the take-up. A new framing mechanism has been devised that permits the double-frame film to be brought into view with a single half-turn movement of the operating button. By merely moving a control button, a single-frame film is brought into view by a quarter-turn of the operating button.

Since the new double-frame films of a given number of frames are twice as long as the single-frame films, and due also to the fact that sound slide-film productions run to much greater length than silent, need for a take-up has been created, and this feature is embodied on the new *S. V. E.* model *AA*. It has a threefold purpose: It not only acts as a take-up for the film, but rewinds it ready for projection, puts it into its own container, and eliminates handling the film except at the ends. A new type of film-can makes it possible to attach the empty can to the bottom of the film-track, the film-can acting as a take-up for the strip of film. It automatically winds the film from the outside to the inside, so that the film is ready for rethreading into the top magazine without the necessity of rewinding or otherwise handling the film.

Up to this time the present single-frame slide-films have seemed to meet the needs in the sales field adequately, and it is our opinion that the industrial motion picture producers will continue to prefer the single-frame as standard for their purpose, but that remains to be seen.

However, a great deal has been said recently in educational circles about the desirability of the use of visual equipment in the classroom where such equipment is as easily available to the teacher as a book or a map. The Picturol method provides just that; and this new tri-purpose equipment with a very portable sound-on-disk reproducer will, we believe, adequately fulfill the daily requirements of the classroom teacher for visual-auditory equipment, accompanied, of course, by the existing single-frame and the resultant libraries of educational double-frame slide-films with sound.

DEVELOPMENTS IN SOUND SLIDE-FILM EQUIPMENT*

F. FREIMANN**

Sound slide-films, or talking still pictures, are being used extensively by large national merchandisers as a sales and training medium. The programs, produced for these organizations on films and disks, are on the subjects of sales and service training, and for inspirational meetings, direct consumer solicitations, and on special subjects such as announcement of changes of company policies, advertising programs, and so forth.

These programs consist of a series of interesting still pictures illustrating the subject matter, manually synchronized with the audible text by the operator, who receives his cues for advancing the pictures from a melodious tone superimposed upon the recording. The pictures are changed as frequently as necessary to follow the sequence of the continuity. Each picture is arrested long enough to illustrate a thought to be absorbed by the audience.

Although the pictures are stills they express action, change with such frequency, and are of such wide variety that interest never lags. The average program of 15

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* Presented at the Spring, 1936, Meeting at Chicago, Ill.

** Electro-Acoustic Products Company, Ft. Wayne, Indiana.

minutes' duration is comprised of not less than 60 excellent pictures. The films are of standard 35-mm. size, and the records are 12- or 16-inch disks, providing a program of 9 to 15 minutes per side.

To most engineers, sound slide-film equipment, and perhaps the medium as a whole, appears very elementary. It is interesting to note, however, that the very simplicity of the medium and the equipment is the foundation of the commercial success that has been attained.

Although some efforts had been made to promote the use of sound slide-films since 1931, during the period of its development only a few commercial organiza-

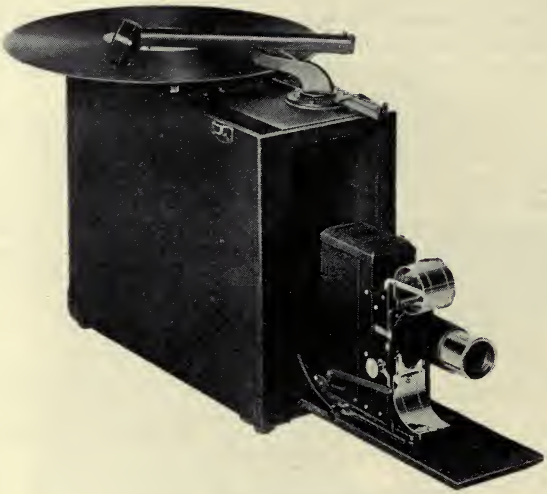

FIG. 1. "Illustravox Senior."

tions adopted the medium, and then exclusively for sales training. In 1933 less than 500 machines were in the field. The excellent results achieved by those organizations using the medium were so conspicuous that, coupled with the aggressive promotion of the film producers and equipment manufacturers, over 200 of the largest national organizations are now operating more than 20,000 equipments distributed throughout this country and abroad. Some of the reasons for the wide and universal acceptance are briefly:

(*1*) The effectiveness of the medium.
(*2*) The simplicity and low cost of sound slide-film productions.
(*3*) The comparatively short time required to produce a complete show.
(*4*) The low cost of duplicates, which can be distributed at the cost of a few dollars per set.
(*5*) The low cost of equipment, making wide distribution possible. This equipment is available at prices ranging from approximately $40 to $120.
(*6*) The portability of the equipment and the simplicity of operation.

The first commercial machines were a rather crude combination of a standard slide-film stereopticon stored in two portable cases housing an amplifier, loud speaker, electrical pick-up, and $33^1/_3$-rpm. motor and turntable. The combination weighed close to 80 pounds. Modern equipment is now available for every purpose. The machines are designed for small group showings, for daylight showings, and for large audiences of up to 200 persons. They weigh from 20 to 40 pounds.

The original combination was modified in various forms to fulfill efficiently the four essential requirements of this type of equipment, namely:

(*1*) Projection of a uniformly sharp picture with sufficient brilliance for showing in a semi-dark room.

FIG. 2. "Salesmaker," with translucent screen.

(*2*) Acceptable quality of sound to provide pleasing reproduction of music and voice with good articulation.
(*3*) Portability: the equipment to be light and compact enough to be conveniently carried by man or woman, in the form of a neat package.
(*4*) Convenience of operation: provide features enabling the operator to set up the apparatus quickly, thread the projector, and show a picture with sound, with a minimum of effort and time.

The *Illustravox Senior* is representative of a machine for sound slide-film presentations to large audiences (Fig. 1). Its compactness is evident. The case is 18 inches high, 17 inches long, and $7^1/_2$ inches wide. The complete unit weighs 38 pounds. It embodies a 200-watt stereopticon capable of projecting a 10-ft. picture of good quality under favorable room conditions. The principal components contained within the case are the projector, the motor and turntable, pick-up, amplifier, and loud speaker.

The projector is mounted upon a cast aluminum door, which is conveniently dropped into the operating position. The metal door provides a firm foundation

for the projector, which when in the operating position is adequately ventilated by being suspended outside the case. The projector is aligned with the screen by a tilting mechanism in the base of the projector. The projectors are equipped with a high-quality optical system designed for maximum efficiency and uniformity of light and sharpness of picture. Ample ventilation of lamp and condensing lenses, coupled with an effective heat-ray filter, minimizing the temperature at the film, insures safe operation under all conditions of temperature and humidity. A comparatively large film magazine accommodating a strip of film fifteen feet long, a receding aperture plate to free the film when in motion, and a highly polished film-track are incorporated to lessen film wear.

A governor-controlled, $33^1/_3$-rpm. motor and comparatively heavy turntable provide the constant record speed. A crystal pick-up is used on a balanced tone-arm because of its light weight and uniform frequency response. It is a high-

FIG. 3. "Illustravox Junior."

impedance device, connected directly to the grid of the first amplifier tube through a potentiometer.

A two-stage amplifier incorporating one type *6D6* tube and two type *43* tubes delivers a power output of 4 watts to the speaker. A voltage-doubler type of rectifier is used in preference to a power-transformer type because of the smaller weight and the adaptibility to universal operation. The amplifier complete with tubes weighs but $2^1/_2$ pounds.

An 8-inch electrodynamic loud speaker is mounted in a steel rim in the side of the case. It is readily detachable for mounting in an identical rim in a separate baffle board. For small group showings the loud speaker remains in the carrying case. For large audiences it is mounted in a small baffle board carried in the record compartment of the case, and is placed below the screen in front of the audience.

The over-all frequency response of the complete sound reproducing equipment from pick-up through the speaker varies only 8 db. over a frequency range extending from 80 to 6000 cps.

A volume control and switches for the projector and motor are mounted upon

the amplifier chassis and are accessible through the tube access door at the rear of the machine. The pictures are advanced by the operator by a remote-control cable. With all the controls directly in front of the operator, he can be comfortably seated behind the machine. When the unit is assembled in its carrying position it contains all accessories, except the screen, necessary for a complete show.

A medium sized machine developed for individual and small group showings, and specifically designed for satisfactory projection under daylight conditions, is represented in the *Illustravox Salesmaker* (Fig. 2). This unit contains all the component parts and accessories required for a complete show. It is in effect a compact, portable little theater. The unit assembled for transportation is $6^1/_2$ inches wide, 18 inches high, and 19 inches long, and weighs only 28 pounds. It can be set up and put into operation in two or three minutes, wherever a power outlet is available.

The center portion of the case incorporates a rubberized silk translucent screen and the loud speaker, and performs the functions of a shadowbox. The front side of the case, when removed, exposes the screen and loud speaker. This section provides storage space for the records. The rear section when dropped down forms the foundation for the amplifier chassis and projector.

The projector is a 100-watt unit mounted upon a substantial aluminum casting which when in the operating position elevates the projector, centering it with the screen. The projector can also be mounted in a plane parallel to the case for projecting a large picture upon a wall screen. Under such conditions the section of the case housing the loud speaker is detached from the base, placed in front of the wall screen, and the speaker connected to the amplifier by means of a flexible cable.

The amplifier, motor, and pick-up are within the metal chassis. The amplifier differs from that of the *Senior* machine in that only one power tube is used in the output stage, providing an output of $2^1/_2$ watts to a 6-inch speaker. The tubes are mounted at the end of the chassis for adequate ventilation and accessibility, and protected with a metal tube guard. The pick-up and motor are identical to those used in the *Senior* model. A wide-angle lens of $1^1/_2$-inch focal length is used to project a picture upon the translucent screen, and a 3-inch focal length lens is carried as an accessory for projecting a picture upon a larger screen.

The *Illustravox Junior* is a very compact, light-weight machine, designed for small group showings and for individual sale presentations (Fig. 3). The case containing all components and accessories including a small screen is only 13 inches high, $15^3/_4$ inches long, and $6^1/_4$ inches wide, and the complete equipment weighs but 20 pounds. It is similar in construction to the *Senior* machine. A 100-watt projector is mounted upon a door in one end of the case which drops down into operating position. The position of the door is adjustable for elevating the projector. The pictures are advanced by means of a remote-control cord extending through the rear of the machine.

The pick-up and turntable are identical to those of the other models. The amplifier is also of the same type, and provides an output of $2^1/_2$ watts to a 5-inch speaker, which is mounted in the side of the case.

All three models described are made for universal operation, working on either direct or alternating current, as well as for alternating current only.

THE DEPARTMENT OF AGRICULTURE'S EXPERIENCE IN THE PREPARATION AND USE OF SLIDE-FILMS*

C. H. HANSON**

The preparation and distribution of 35-mm. slide-films was first undertaken by the Department of Agriculture in 1926. The demand for these slide-films has grown with surprising rapidity. Last year 11,200 positives were sold from the Department's negatives. The interesting thing to note in this connection is that during the same period the demand for the glass lantern-slides of the same subjects dropped to such a low level that the Department no longer feels justified in preparing lantern-slide sets of its new lectures.

To increase the availability of its illustrated lectures on slide-films, the Department annually lets a contract to some commercial concern for the production of its negatives and the production and distribution of its positives. The low price established for these slide-films has undoubtedly been an important factor in getting people to use them. The present price of a slide-film having no more than 48 frames is 50 cents. The lecture notes to accompany the slide-film are supplied free.

Production Problems.—The production of high-grade slide-films involves a number of technical difficulties not inherent in making glass slides. From a practical point of view the big problem of making a slide-film is how to copy a series of illustrations of various kinds and sizes in a single film so as to maintain uniformly high quality in the reproduction of full-tone photographs and good legibility in drawings, charts, and reading matter. The difficulties involved in the Department's work are made more complicated by the requirement that the negative must be sufficiently uniform in printing density to permit its being run in a motion picture printer on one light.

The ideal condition for best results is, of course, to have all copy of such size as to require the same amount of reduction. As we have found it impracticable and too expensive under our conditions to do this, we make the most of our situation by concentrating our efforts upon the quality and format of the original copy. We prefer photographs rich in detail and halftones and having normal contrast. Prints that are contrasty or have large areas of highlight are least satisfactory. With the exception of prints on which handwork is required, all prints are made upon glossy paper and ferrotyped. The prints are dry mounted upon black cardboard, 9 × 11 inches in size.

Size of Copy and Picture Aperture.—The writer believes that real progress in the improvement of slide-films can not take place until a larger size of picture aperture is established as standard. The present standard 35-mm. aperture is

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* Presented at the Spring, 1936, Meeting at Chicago, Ill.

** U. S. Department of Agriculture, Washington, D. C.

too small and it will be only a matter of a relatively short time before a larger size will be used. The limitations imposed by the small picture aperture greatly increase the difficulties involved in preparing the copy and making the negatives.

Reproduction of Detail.—The value of many of the slide-films prepared by the Department of Agriculture depends largely upon the satisfactory reproduction of detail in the original photographs. A little thought will make it clear that an excessive degree of reduction of fine detail in the original will compress the details to such an extent as to exceed the resolving power of the emulsion of the film. Therefore, under present conditions it is especially desirable to avoid the use of large prints when the reproduction of fine detail is important. When the subject permits, it is well to trim down large prints and thus obtain better detail. Trimming is also highly useful in eliminating nonessentials and thus giving emphasis to the real subject of interest.

When trimming prints, when it is possible to do so, it is always advantageous to trim to the same format as that of the picture aperture. The advantages are that it affords the maximum size of negative image and, in addition, a more pleasing screen image because the photograph extends to the edge of the frame.

Legibility: Its Importance and How to Obtain It.—All the Department's slide-films contain more or less reading matter, and many contain charts and drawings; it is this type of material that gives us our most serious problems. The work is done on the assumption that if the screen image is not easily legible it is of little educational value. For this reason we constantly strive to get our coöperators to simplify and clarify their drawings, charts, *etc.*, and to get our artists to keep down the size of the drawings and make the lines and lettering heavy and bold.

Legibility of Black-and-White Copy.—The problem of preparing black-and-white copy that will reproduce well in slide-film form is a very real one, so much so that the Bureau of Agricultural Economics has found it necessary to prepare two series of charts, one for publication and another for use in slide-films. Thus, we have found by experience that copy that is well adapted for publication will often not be satisfactory for slide-films.

In general, we have found that to attain legibility on the screen it is necessary to limit the material to about 30 to 35 words, with 50 as the extreme limit. It may be of interest also to note that tests indicate that the width of a line of printed matter should not exceed 28 or 30 letters and spaces for good legibility. More definite information along these lines for the guidance of those preparing copy is much needed, and it is to be hoped that some qualified agency will undertake such studies.

Lettering and Printed Matter.—The legibility of charts, reading matter, *etc.*, naturally depends largely upon the copy, and merits much more study than has been given it. It is our opinion that hand-lettering is too slow and expensive, and, it should be added, too frequently lacking in legibility. Ordinary typewritten material should not be used, except in emergency. A small hand printing press is most satisfactory, and the use of type should be encouraged. It is doubtful whether there is any other practical process which will afford the legibility, variety, and quality at a given cost that can be attained with type. It may be interesting to know that the drafting section of the Bureau of Agricultural Economics is now using a hand-press for printing most of the lettering used on their

statistical charts. The printing is done upon a fine grade of tissue paper, which is treated by a commercial process. The printed matter is cut up and pasted to the chart. The advantage of the method is that it practically does away with blocking out the negative, *etc.*, in addition to reducing the cost and time required to do the lettering.

Most persons prefer white on black, rather than black on white lettering for slide-films. Many of our white on black illustrations have been hand-lettered with Chinese white, to which is usually added a little glycerin. When fresh, this kind of lettering is quite satisfactory, but unfortunately the Chinese white is easily rubbed off. Information is needed on how to overcome such difficulties in hand-lettering.

Printing with white ink upon black paper can be successfully done, but requires more than usual care and skill. A simple and satisfactory method suggested by J. I. Crabtree has been used with satisfaction. It consists in printing with black ink upon a gaslight paper such as Azo, then exposing the paper to light, developing, and then removing the ink with gasoline or benzine.

Shape of Aperture.—Another matter that merits attention is the shape of the picture aperture. Rounded corners may be all right for motion pictures, but they certainly are not suitable for slide-films. The truth of this statement is at once apparent when the subject is a narrow vertical photograph placed at one side of the frame, as is often done to make use of the remainder of the space for lettering. If such copy is made to fill the frame, the outer corners of the photograph are rounded and the inner ones are square. This can be overcome by decreasing the size of the image, but that is an unsatisfactory solution of the problem. The corners of the aperture should be square, or but slightly rounded.

Negative and Positive Problems.—Since the miniature camera came into its own, the importance of graininess is quite fully recognized, and considerable research work has been done on the problem. But more work should be done with special application to slide-film making. Much that has been learned about the production of fine-grain miniature negatives applies also to slide-films. However, we must not lose sight of the fact that although the typical low-contrast miniature negative may be quite suitable when used in a condenser type of enlarger for making a print on a rather contrasty grade of paper, yet a similar slide-film negative will very likely give poor results when printed upon positive film for projection purposes. The uses to which the two kinds of negative are adapted are quite different, and it is evident that if each is to serve its purpose most effectively they must differ in density and gamma. Here is an opportunity for the research worker to come to the aid of the practical worker in this field who needs more definite information upon the kind of negative required for best results and how to attain them. In addition, we need information on the type of positive that will give the most satisfactory results in a projector using a 50-watt lamp, a 100-watt lamp, *etc.* At present no one seems to know.

In addition to the problems already discussed, we have those of fog, halation, and lack of precise definition. Fog and poor definition are usually the result of defective equipment, or carelessness, or both. Two questions are pertinent here: (*1*) what type of lens is best suited to this kind of work, and (*2*) what is the best method of obtaining precision focusing? Upon the subject of halation it may be said that, judging from exoerience in making lantern slides, we can not expect to

attain the best results until we take to the use of non-halation films, both negative and positive. It is also believed that the films now commonly used in the production of slide-film negatives are not the best for the purpose. It would be a great help if some practical method could be devised for treating these films so as to reduce to a minimum the scratching which under present conditions takes place rapidly. Needless to say there is a growing demand for slide-films in color.

Projection Problems.—As previously stated, it is the writer's belief that the development of slide-film work has been much retarded because of the size of the picture aperture chosen as standard by those who pioneered the work. The choice made was a natural one. Nevertheless it was undoubtedly a serious mistake so far as results are concerned. Those in the Department of Agriculture who have given this matter serious study are convinced, in the light of the disappointing results attained with present materials and equipment, that we can not hope to achieve the improvement desired until an aperture of larger size is established as standard. A larger width of film, such as 70 millimeters, might be the best solution, but in view of the fact that the Leica or Contax size (24 × 36 mm.) is now a standard miniature camera size the world over, that precision cameras of the highest order are now readily available, and that printers and projectors are also available, we are rather strongly inclined to believe that the Leica size of frame would be the most practical solution of the problem. A third choice might be a square picture aperture of the maximum size permissible on 35-mm. film, possibly unperforated. If the aperture were square, there would be no need of supplying the projector with a revolving front, which is an indispensable feature of any good projector for Leica slide-films. In considering this problem, however, the desirability of establishing the 2 × 2-inch glass slide as a substandard size should be kept in mind, as its development will be greatly influenced by the market supply of projectors adapted to its use. The size of the condenser that will cover a slide made on a 2 × 2-inch plate is also well suited for use in projecting 24 × 36-mm. slide-film frames.

DISCUSSION

MR. GREENE: What wattage lamp was used in Mr. Freimann's projector?

MR. FREIMANN: 200-watt, with the beaded screen.

MR. CRABTREE: Referring to Mr. Hanson's paper, I realize it must be difficult to obtain slide-films of uniform quality from submitted subject matter of varying quality. I understand that they are rephotographed or recopied in order to level up the contrast in the photographic film.

An alternate scheme would be to use duplicating positive film for the negative film in the copying camera. This film has properties such that by using either a yellow or a violet filter over the lens when copying, the contrast of the negative can be varied, even though all the images are developed for the same time. Those who are doing this kind of work may find this a very useful way of levelling up the contrasts without changing the time of development.

MR. MATTHEWS: Mention was made of scratches encountered in a good many of these slide-films after they have been used for some time, and I wonder whether varnishing the surfaces would not be worth considering as a means of overcoming that objection.

MR. MACHARG: There are several solutions on the market for that purpose.

One advantage of the single slide-film is that you do protect it, by reason of the fact that the positive is at the center of the film, which is 3 inches long and $1^3/_4$ inches wide, and you do not handle it. By making a little photopack envelope you can protect the single slide-film absolutely without interfering with its use. Varnishing is not satisfactory; I have tried it, but it does not work so well.

MR. GREENE: In the theatrical field we are still a long way from ideal conditions in handling film. It would seem that thorough attention to the design of slide-film projectors and equally thorough attention to handling the film would very markedly reduce the trouble due to cracking. If a slide-film is used, say, twice a month, that is not excessive, is it? Two hundred showings would mean 100 months, which gives the film a life of something like eight years.

Another thing that impressed me in the demonstrations was that in one of the slides a pillar in the foreground at the lower right-hand corner of the screen was in fairly good detail, while the right-hand background of the picture was practically invisible. A duplicate was placed upon the screen with the glass slide a few minutes later, and all detail in that part of the picture was visible. If they were duplicates, it would seem to show there was a very decided lack of illumination from the slide-film projector. There apparently seems to be an attempt by those who use them to try to use them in fields for which their limited beam power makes them unsuitable.

Another thing: Would it not be possible or feasible to design the slide-film projectors so that with the same mechanism the lenses might be interchangeable, and so that the high-grade, high-quality photographic lens in the camera might be inserted into the bayonet mount on the front of the projector; or would the heat of the beam prove detrimental to the lenses?

MR. COOK: The lenses can be cemented in such a way that the heat from the projector will not damage them in any way.

MR. FREIMANN: It might be remembered that sound slide-films are necessarily restricted to equipment, the price of which is a very definite consideration, and very seldom is the camera available with every sound slide-film or stereopticon projector. The lenses that are now used are the most practical, commercially, from the price and quality standpoint. You probably have observed that the pictures were quite effective with a 200-watt projector, and after all, the medium is intended for showings to comparatively small groups, and should not be compared to theatrical showings to audiences in excess of 500 persons.

MR. WOLF: Can someone tell us the extent to which the slide-film is being used in industry and in the schools.

MR. FREIMANN: I am not thoroughly familiar with the amount of film used in the educational field. However, the average commercial slide-film is from seven to fifteen feet long. Some of the motor companies are releasing programs twice a month, having circulations as great as 5000 to 7000 copies. That will furnish some idea of the extent to which the medium is used and the amount of film consumed.

MR. GREENE: As regards the high-grade lenses, a bayonet mount for the front of the projector could be made more cheaply than the lens could be made, and the great number who have their own miniature cameras could then purchase the projectors ready for use at a much lower price than if the product were already equipped with a lens.

MR. CRABTREE: Mr. Hanson, what is the maximum screen size that you recommend, and what is the maximum size of audience that usually views them with any degree of comfort? There is no question, judging from the samples shown, that the quality of the image from the standpoints of brightness and definition does not compare with that of the glass slide.

MR. HANSON: The average size of our audiences is about 50, and for such groups we seldom project pictures larger than 5 or 6 feet wide. With regard to lack of definition in a few of the Leica-size frames, that is due to the negatives being out of focus. Unfortunately, we found it impossible to have the slide-film remade before this meeting.

Nevertheless, I not only agree with Mr. Crabtree that the image of the glass slide is superior to that of the slide-film in both quality and brilliance, but confess to a personal preference for glass slides in my own work. Public service must, however, take precedence over personal preference. It is the duty of our office to make our illustrative material available in a form most acceptable and useful to our 7000 extension workers located in all the agricultural sections of the country. We are giving up glass slides only after having thoroughly tried them out for 25 years and found them not adapted to the needs of our country agents. As previously shown, the demand for our slide-films has grown by leaps and bounds. That explains why we are gradually dropping glass slides and giving our attention to slide-films. We realize quite fully the deficiencies of the slide-film, and that is why I recommend the adoption of a larger size of aperture, which, I am sure, will do much to increase materially the efficiency and usefulness of this very valuable visual aid.

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TECHNICAL SESSIONS

All technical sessions will be held at the Sagamore Hotel (Convention headquarters) except the session on Tuesday morning, which will be held in the auditorium of the Kodak Research Laboratories at Kodak Park.

HEADQUARTERS

The Headquarters of the Convention will be the Sagamore Hotel, where excellent accommodations are assured. A reception suite will be provided for the Ladies' Committee.

Special hotel rates guaranteed to SMPE delegates, European plan, will be as follows:

One person, room and bath	$ 3.50
Two persons, room and bath	6.00
Parlor suite and bath, for two	10.00
Parlor suite and bath, for three	12.00

Everyone who plans to attend the convention should return his room reservation card to the Hotel promptly in order to be assured of satisfactory accommodations. Registrations will be made in the order in which the cards are received. When the Sagamore Hotel is booked to capacity, additional accommodations will be provided by the Hotel Arrangements Committee at another hotel in the immediate vicinity of the Sagamore.

A special rate of fifty cents a day has been arranged for SMPE delegates who motor to the Convention, at the Ramp Garage, near the Hotel.

Golfing privileges may be arranged for any of the Convention delegates by consulting the Chairman of the Local Arrangements Committee.

REGISTRATIONS

Registration Headquarters will be located on the Sagamore Roof. All members and guests are expected to register, as admittance to certain sessions may be contingent upon the display of a membership badge or special ticket. Admit-

tance cards will be issued at the registration desk for the special lecture on Monday evening and for the invitation luncheons on Tuesday and Wednesday noons at Kodak Park and the Bausch & Lomb Optical Company, respectively. Reservations for the Informal Luncheon on Monday and for the Banquet on Wednesday should be made at the registration desk.

Identification cards will be honored at Loew's *Rochester* and the *Century* and *Palace* Theaters, the latter two through the courtesy of the Monroe Amusement Company.

LADIES PROGRAM

A tea has been arranged for the ladies at the *University Club* on Monday afternoon, October 12th. On Tuesday there will be a luncheon at one of the country clubs, followed by a motor trip around the city. The program for Wednesday is being arranged and will be announced later. Thursday will be left open for shopping trips and visits to the new Rundel Memorial Library, the Art Gallery, and Eastman School of Music.

ROCHESTER RESTAURANTS

In addition to the Main Dining Room and the Coffee Shop at the Sagamore Hotel, where excellent meals may be obtained, there are several leading restaurants in the downtown district, as follows:

Laube's Old Spain, 11 East Avenue
Odenbach's Restaurant, 14 South Avenue
Odenbach's Coffee Shop, Clinton and Main (Dinner Dancing)
1078 University Ave. A reasonably priced family restaurant
Manhattan Restaurant, 25 East Avenue
Seneca Hotel, 26 Clinton Avenue S.

INVITATION LUNCHEONS AND INSPECTION TRIPS

The Eastman Kodak Company has invited all visiting members of the Society to a complimentary luncheon at Kodak Park on Tuesday, October 13th at 1:10 P.M. Inspection trips through the Kodak Park Works and the Kodak Research Laboratories will be arranged during the afternoon.

On Wednesday, the Bausch & Lomb Optical Company has invited all visiting members to a complimentary luncheon at their plant on St. Paul Street at 1:10 P.M. An inspection tour of the plant and the Scientific Bureau will be arranged following the luncheon. A special trip through the B & L glass plant will start at 8:30 A.M. (at the plant) Wednesday morning.

The details of several other trips, for which reservations should be made, are as follows:

Stromberg Carlson Telephone Manufacturing Co., 100 Carlson Road.—Two-hour trip, including engineering and acoustical research laboratories and manufacture and assembly of radio sets and telephone equipment.

Delco Appliance Corporation, 391 Lyell Ave.—Two-hour trip Tuesday and Wednesday afternoons. Trip includes examination of finished product display, visit to engineering laboratories, and tour of the plant departments housing interesting product operations. Registration for visit desired.

Gleason Works, 1000 University Avenue.—One-hour trip showing manufacture and assembly of gear machinery. Advance registration desired.

Taylor Instrument Co., 95 Ames St.—Two-hour trip showing manufacture of clinical and household thermometers, aneroid barometers, industrial temperature recorders and controllers, *etc.* Engineering and Research Laboratories and special display of instruments in operation. Advance registration desired.

Wards Natural Science Establishment, 302 N. Goodman St.—This firm specializes in supplying models for museums, schools, and colleges. Trips may be arranged at any time without previous registration.

It is assumed that delegates will arrange for their own transportation for all industrial trips with the exception of those to the Bausch & Lomb Optical Co. and the Kodak Park Works of the Eastman Kodak Co., for which motor-coach service will be provided on the dates specified.

POINTS OF INTEREST

The University of Rochester.—The University occupies two sites, the original location between Prince and Goodman Streets on University Avenue, and the River Campus in the southwest section of the city. For nearly seventy years after its organization the University was operated as a Liberal Arts College, but in 1918 the School of Music was organized through the generosity of the late George Eastman, and the school now bears his name. In 1921 it occupied modern buildings in the downtown section of the city, including the beautiful Eastman Theater. This theater is one of the chief cultural centers of the city, being the home of the Rochester Philharmonic Orchestra and the Civic Orchestra, and being the scene of many other musical and dramatic events.

In 1920 the School of Medicine and Dentistry was organized with a generous endowment provided largely by Mr. Eastman and the General Education Board.

The Bausch & Lomb Memorial Laboratory, housing the Department of Physics and the Institute of Optics, is located on the River Campus. This Institute was organized through the coöperation of Rochester optical industries, for the purpose of providing a center of teaching and research in the field of optics.

The total enrollment of all departments of the University exceeds 4000 students.

The Genesee River.—At the south edge of the city the river connects with the New York State Barge Canal. A barge channel is maintained to the center of the city at the Court Street dam. Below the dam the river enters a rocky bed and passes over five waterfalls having a total drop of 267 feet. These falls supply 50,000 horsepower to the city's industries. At the foot of the falls the river enters a deep gorge, through which it flows to its mouth on Lake Ontario, seven miles north of the business district. A drive north on St. Paul Street along the river to Veterans' Memorial Bridge which spans the gorge, and then across the bridge and north on Lake Avenue to the lake will be well worth while. Two city parks, Maplewood and Seneca, occupy opposite banks of the gorge near the Veterans' Bridge. Ontario Beach Park at the north end of Lake Avenue has a fine public bathing beach.

East Avenue.—This is one of the finest residential streets in this part of the country, extending from the downtown district east and south to Pittsford. At 900 East Avenue is located the former home of George Eastman, bequeathed

by him to the University and now occupied by the President of the University of Rochester.

Colgate-Rochester Divinity School.—The campus is situated on a beautiful hill adjacent to Highland Park. It consists of a group of fine modern buildings grouped around the Divinity Tower, a dominating feature of the landscape. This school, organized in 1928 by the Baptist Education Society, combines and continues the activities of the Colgate Theological Seminary, formerly of Hamilton, N. Y., and the former Rochester Theological Seminary. About 100 students are enrolled.

Durand Eastman Park.—This beautiful park extends for two miles along the shores of Lake Ontario and extends back through rolling hills covered with trees and flowers of many varieties. There is a bathing beach and public golf course. The park is reached by driving north on Culver Road to the park entrance.

Genesee Valley Park.—Located along the river adjacent to the River Campus of the University. Contains a public golf course, playgrounds, and picnic sites.

Highland Park.—A few minutes drive from the River Campus (east on Elmwood to Goodman, north to the park). Contains 3900 varieties of trees, shrubs, and perennials. Particularly noted for its display of lilacs, peonies, and azaleas.

Mendon Ponds Park.—A few miles southeast of the city, reached over routes *15* and *65*. The site of an old camping ground of the armies of the expedition against the Seneca Indians. Contains three ponds, bridle trails, and picnic grounds.

Powder Mill Park.—On the site of an old, carefully hidden powder mill. Contains a trout fish hatchery, and is a favorite picnic site. Located fifteen miles east of the city on route *15*.

Letchworth Park.—Located on the upper Genesee River about 50 miles south of Rochester. Contains some of the most notable waterfalls and river-gorge scenery in the eastern United States. Roads and foot-trails lead to three large falls, along the edge of deep rocky gorges and the deep wooded canyon below the falls. Picnic sites of unusual beauty abound, and there are cabins for the overnight visitor. Take routes *35–253–36–245*.

The Finger Lake Region.—This famous scenic region of lakes, hills, and waterfalls lies within an hour's drive to the south and east of Rochester, and offers dozens of motor trips through country of unusual beauty. There are six large lakes, the two largest of which, Seneca Lake and Cayuga Lake, are nearly forty miles in length. They are surrounded by wooded hills which rise to an altitude of 2300 feet. There are nine state parks covering an area of 5000 acres and containing 1000 waterfalls and many scenic gorges. Visitors driving from Rochester to Ithaca will pass through the heart of the region. Several routes may be chosen passing through points of particular interest. Information and road maps for this trip may be obtained at the registration desk, where there will also be available maps for those wishing to plan more extended trips.

Niagara Falls.—Ninety miles west of Rochester. May be reached over route *104*.

TENTATIVE PROGRAM

MONDAY, OCTOBER 12th

9:00 a. m.	**Registration;** *Sagamore Hotel Roof.*
10:00 a. m. to 12:00 p. m.	*Sagamore Roof;* **Business and General Session.** Opening Remarks by President H. G. Tasker. (10 Min.) Report of the Convention Committee; W. C. Kunzmann, *Convention Vice-President.* (5 Min.) Society Business. (20 Min.) Election of Officers for 1937. Report of the Secretary; J. H. Kurlander. Report of the Treasurer; T. E. Shea. Report of the Membership Committee; E. R. Geib, *Chairman.* "Slide Rule Sketches of Hollywood;" H. G. Tasker, Universal Pictures Corp., Universal City, Calif. (20 Min.) "The Development of the Art and Science of Photography in the Twentieth Century;" (*Illustrated*) C. E. K. Mees, Eastman Kodak Company, Rochester, N. Y. (1 Hour.)
12:30 p. m.	*Main Dining Room*; **Informal Luncheon.** For members and guests. Address of Welcome by the Hon. Charles Stanton, Mayor of Rochester; Response by President Tasker. Speakers: Dr. Howard Hanson, *Director*, Eastman School of Music; and others whose names will be announced later.
2:00 p. m. to 5:00 p. m.	*Sagamore Hotel Roof;* **Sound and Apparatus Session.** Report of the Sound Committee; P. H. Evans, *Chairman.* (15 Min.) "A Record Word-spotting Mechanism;" R. H. Heacock, RCA Manufacturing Co., Inc., Camden, N. J. (25 Min.) "Modern Loud Speaking Telephones and Their Development;" C. Flannagan, R. Wolf, and W. C. Jones, Electrical Research Products, Inc., New York, N. Y. (25 Min.) "A Review of the Quest for Constant Speed;" E. W. Kellogg, RCA Manufacturing Co., Inc., Camden, N. J. (25 Min.) **Symposium on Projector-Testing Devices.** "A New Type of Peak Reading Volume Indicator;" F. L. Hopper, Electrical Research Products, Inc., New York, N. Y. (15 Min.) "A Neon Type Volume Indicator;" S. Read, Jr., RCA Manufacturing Co., Inc., Camden, N. J. (15 Min.)

"A Neon Tube Oscilloscope as a Utility Instrument for the Projection Room;" F. H. Richardson, *Motion Picture Herald*, New York, N. Y., and T. P. Hover, Ohio Theater, Lima, Ohio. (*Demonstration*) (15 Min.)

"The Schwarzkopf Method of Identifying Criminals;" J. Frank, Jr., International Projector Corp., New York, N. Y. (*Demonstration.*) (20 Min.)

"Medical Motion Pictures in Color;" H. B. Tuttle, Eastman Kodak Co., Rochester, N. Y. (*Demonstration.*) (20 Min.)

Demonstration Film Showing Several Applications of Photography with Polarized Light. (*Courtesy of American Society of Cinematographers, Inc., Hollywood, Calif.*) (15 Min.)

8:15 p. m. *Eastman Theater;* **Special Lecture Demonstration.**

"Color Photography" (with demonstrations and motion pictures); C. E. K. Mees, *Vice-President* and *Director of Research*, Eastman Kodak Company, Rochester, N. Y.

TUESDAY, OCTOBER 13th

9:00 a. m. Buses will be at the Sagamore Hotel to transport members and guests to the Kodak Research Laboratories at Kodak Park.

10:00 a. m. to 1:00 p. m. *Auditorium, Kodak Research Laboratories;* **General Technical Session.**

"The Kodak Research Laboratories;" C. E. K. Mees, Eastman Kodak Co., Rochester, N. Y. (15 Min.)

"Manufacture of Motion Picture Film;" E. K. Carver, Eastman Kodak Co., Rochester, N. Y. (25 Min.)

"Stability of Motion Picture Film as Determined by Accelerated Aging;" J. R. Hill and C. G. Weber, National Bureau of Standards, Washington, D. C. (25 Min.)

"The Care of Slide-films and Motion Picture Film;" C. G. Weber and J. R. Hill, National Bureau of Standards, Washington, D. C. (25 Min.)

"Fire Protection in the Motion Picture Industry;" H. Anderson, Paramount Pictures, Inc., New York, N. Y. (25 Min.)

"The Projection of Lenticular Color-Films;" J. G. Capstaff, O. E. Miller, and L. S. Wilder, Eastman Kodak Co., Rochester, N. Y. (*Demonstration.*) (25 Min.)

1:10 p. m. Invitation Luncheon at the Kodak Park Plant of the Eastman Kodak Company.

2:00 p. m. to 5:00 p. m. Inspection tour of Kodak Park and the Kodak Research Laboratories.

WEDNESDAY, OCTOBER 14th

9:30 a. m. to 12:15 p. m. *Sagamore Hotel Roof;* **Optics and Lighting Session.**

"The Art of Lighting;" G. J. Folsey, Jr., Hollywood, Calif. (20 Min.)

"Effect of Lens Aberrations upon Image Quality;" W. B. Rayton, Bausch & Lomb Optical Co., Rochester, N. Y. (25 Min.)

"Mercury Arcs of Increased Brightness and Efficiency;" L. J. Buttolph, General Electric Vapor Lamp Co., Hoboken, N. J. (*Demonstration.*) (25 Min.)

Report of the Studio Lighting Committee; R. E. Farnham, *Chairman.* (15 Min.)

"Recent Developments of High-Intensity Arc Spotlamps for Motion Picture Production;" E. C. Richardson, Mole-Richardson, Inc., Hollywood, Calif. (15 Min.)

"Trick and Process Cinematography;" J. A. Norling, Loucks & Norling Studios, New York, N. Y. (*Demonstration.*) (20 Min.)

"A Third-Dimensional Effect in Animated Cartoons;" J. E. Burks, Fleischer Studios, New York, N. Y. (*Demonstration.*) (15 Min.)

1:10 p. m. Invitation Luncheon at Bausch & Lomb Optical Company. Transportation to the Bausch & Lomb Plant will be provided. Buses will leave the Sagamore Hotel at 12:30 p. m. *sharp.*

2:00 p. m. to 5:00 p. m. Inspection Tour of Bausch & Lomb and Scientific Bureau.

7:30 p. m. *Oak Hill Country Club;* **Semi-Annual Banquet.**

Motorcoach transportation will be provided to and from the Club by the Transportation Committee. Coaches will leave the Sagamore Hotel promptly at 7:00 p. m.

Presentation of SMPE Journal Award.

Presentation of SMPE Progress Medal.

Addresses by Mr. M. H. Aylesworth, *Chairman of the Board of Directors* of RKO Radio Pictures, Inc., and other eminent members of the industry whose names will be announced later.

Dancing and entertainment.

THURSDAY, OCTOBER 15th

9:30 a. m. to 12:15 p. m. *Sagamore Hotel Roof;* **Apparatus and Equipment Symposium.**

"A Film-Editing Machine Embodying Optical Intermittent Projection;" J. L. Spence, Akeley Camera Co., Inc., New York, N. Y. (15 Min.)

"New Recording Equipment" and "An Improved Reel-end Alarm;" D. Canady and V. A. Wellman, Canady Sound Appliance Co., Cleveland, Ohio. (25 Min.)

"Three-Wire Direct-Current Supply for Projector Arcs;" C. C. Dash, Hertner Electric Co., Cleveland, Ohio. (15 Min.)

"A Demonstration Triode Tube;" F. E. Eldredge and H. F. Dart, Westinghouse Lamp Co., Bloomfield, N. J. (*Demonstration.*) (15 Min.)

Report of the Standards Comm ttee; E. K. Carver, *Chairman.* (15 Min.)

"The Use of Visual Equipment in Elementary and Secondary Schools;" C. M. Koon, Office of Education, U. S. Department of the Interior, Washington, D. C. (20 Min.)

2:00 p. m. to 5:00 p. m. *Sagamore Hotel Roof*; **Laboratory Session.**

"The Performance Record of an Automatic Recording Densitometer;" C. M. Tuttle and M. E. Russell, Eastman Kodak Co., Rochester, N. Y. (20 Min.)

"A Developing Machine for Sensitometric Work;" L. A. Jones, M. E. Russell, and H. R. Beacham, Eastman Kodak Co., Rochester, N. Y. (*Demonstration.*) (30 Min.)

"Some Aspects of Reduction Printing;" G. Friedl, Jr., Electrical Research Products, Inc., New York, N. Y. (25 Min.)

"Influence of Sprocket Hole Perforations upon the Development of Adjacent Sound-Track Areas;" J. G. Frayne and V. Pagliarulo, Electrical Research Products, Inc., Los Angeles, Calif. (25 Min.)

"Improvements in Lenticulated Film;" E. Gretener, Siemensstadt, Germany. (15 Min.)

APPARATUS EXHIBIT

There will be no general apparatus exhibit because of the limited display space at the Convention headquarters. The Papers Committee, however, is arranging the usual Apparatus Symposium on Thursday morning, and would like to be notified of any additional papers for this session.

ABSTRACTS OF PAPERS FOR THE ROCHESTER CONVENTION OCTOBER 12–15, 1936

The Papers Committee submits the following abstracts of papers for the consideration of the membership. It is hoped that the publication of these abstracts will encourage attendance at the meeting and facilitate better discussion of the papers.

G. E. Matthews, *Chairman*

C. N. Batsel	M. E. Gillette	H. B. Santee
L. N. Busch	E. W. Kellogg	T. E. Shea
A. A. Cook	R. F. Mitchell	P. R. von Schrott
L. J. J. Didiee	W. A. Mueller	I. D. Wratten

"The Development of the Art and Science of Photography in the Twentieth Century;" C. E. K. Mees, *Eastman Kodak Co.*, Rochester, N. Y.

An account of the developments in practical photography during the past thirty-five years and of the progress that has been made in our knowledge of the scientific principles of photography.

"A Record Word-Spotting Mechanism;" R. H. Heacock, *RCA Manufacturing Co., Inc.*, Camden, N. J.

A word-spotting mechanism is described, which replaces the pick-up needle upon a predetermined spot of a phonograph record by pressing a remote release button after setting three reference readings previously established by the trial and error method.

The pick-up arm is held poised above the record by a direct electromagnetic pull upon the back end of the pick-up arm. When this electromagnet is de-energized the pick-up falls, due to the pull of gravity.

The speed of fall may be controlled by means of an adjustable exhaust port on an air dashpot. No catches or latches are used to release the arm. A manually operated open-circuiting release button is in parallel with a second open-circuiting switch in the electromagnet circuit, and this second switch is opened each revolution of the turntable by a fixed cam. To release the pick-up, the manually operated button is depressed, but the pick-up is not released until the second switch is cammed open by the turntable.

In this way the device is indexed with relation to the radial position of the record so that not only may the correct groove be repeatedly selected, but the desired portion of the groove may be consistently repeated. The effect of eccentricity of the record center hole with relation to the recorded grooves is eliminated. Variations in the size of the record hole are accommodated by means of a tapered centering pin.

Each of the mechanical parts, with the exception of the cammed turntable switch, is rigidly located upon the single pick-up arm unit. All necessary electrical parts for complete operation of the mechanism on a 105- to 125-volt, 50- to 60-cycle supply are located on the underside of the motor board.

"Modern Loud Speaking Telephones and Their Development;" C. Flannagan, R. Wolf, and W. C. Jones, *Electrical Research Products, Inc.*, New York, N. Y.

The subject of modern loud speaking telephones is discussed with reference to efficiency, power-handling capacity, response-frequency characteristics, and distributional characteristics. Improvements and their significance are pointed out. The latest types of loud speaker are described and certain development problems discussed.

"A Review of the Quest for Constant Speed;" E. W. Kellogg, *RCA Manufacturing Co.*, Camden, N. J.

The importance of constant record speed in machines used for reproduction of music was realized by Edison and many other pioneers in sound recording. Crude performance from other standpoints made it hardly worth while for the earlier workers to attempt to obtain extremely high standards of speed constancy.

The flyball type of phonograph governor came into the picture and has been worked so well that it has not even yet been superseded, although with synchronous motor drives for certain types of equipment, the governor is no longer necessary.

Recording sound photographically probably began with the work of Alexander Graham Bell, who made records upon glass disks; but not until long celluloid films were available and the motion picture became thoroughly established, did photographic sound recording become a competitor of the disk. As late as 1930 there were many engineers who advocated the disk for sound picture work.

While the same general principle applies to both mechanical and photographic records, the latter involves certain additional problems.

Among the earlier workers in this field, the expedients adopted by C. A. Hoxie and C. L. Heisler, of the General Electric Company, deserve recognition. Brief descriptions and discussions are given of a number of ingenious arrangements for improving speed constancy which have been employed by various inventors and engineers. Some of these expedients have been applied to record turntables and some to film equipment.

"The Schwarzkopf Method of Identifying Criminals;" J. Frank, Jr., *International Projector Corp.*, New York, N. Y.

At the present time there are only two means of sight identification generally in use—the still picture and the police headquarters line-up. Neither is particularly effective. The use of a sound motion picture which can be easily exhibited to widespread audiences in a short space of time is already regarded as one of the most useful developments in this field. Sound-film recording equipment of both the single- and the double-film type, and for both 16-mm. and 35-mm. technic, has been developed that provides for a picture about $3^1/_2$ minutes long. The special apparatus and the technic developed are described, and actual motion pictures of actor-criminals shown to prove the effectiveness of the method.

"Medical Motion Pictures in Color;" H. B. Tuttle, *Eastman Kodak Co.*, Rochester, N. Y.

Improvements made during the past year in methods, apparatus, and materials used in making medical motion pictures, particularly Kodachrome, and the characteristics of an emulsion suitable for exposure with artificial light are discussed. The uses of special accessories for medical motion picture photography are de-

scribed. A demonstration medical film will be shown at the conclusion of the paper.

"Color Photography;" C. E. K. Mees, *Eastman Kodak Co.*, Rochester, N. Y.

All processes of color photography depend upon splitting the light into the three primary colors—red, green, and blue-violet—making three separate pictures by the three colors, and then combining the three pictures again when they are viewed.

In the earliest processes, three quite separate negatives were made; from them three positives were made; and the latter were projected by means of three optical lanterns through suitable color filters so that the images fell on top of one another upon the screen and produced a color picture. Then methods were invented by which a multitude of tiny color filters covered the whole surface of the film, these filters being so small that they are invisible to the unaided eye. The picture taken through the filters and then viewed through the filters again is thus composed of a multitude of units, each of which is taken and viewed by one of the three primary colors.

A process similar to this is the lenticular film process, in which the film base is covered with microscopic lenses which form images of the three filters on the film. The three images are then projected again through the three filters fitted to the lens of the projector.

Another method of making the color pictures is to print each of the separation negatives, making the prints of colors complementary to the filters through which the pictures were taken; and then superimposing the prints so that the red filter negative is printed in blue-green; the green filter negative in magenta; and the blue filter negative in yellow. Essentially, this is the process used in producing color reproductions in magazines, each of the separate pictures being printed in its suitably colored ink and the printings being superposed.

In the multilayer processes, the three separation pictures are made in the depth of the film. The film has superimposed layers, each of which is sensitive to one of the primary colors. After exposure, the three images are converted into dye colors, either by the selective bleaching of dyes present in the coating or by the formation of dyes in the layers—by coupler development, for instance.

"Manufacture of Motion Picture Film;" E. K. Carver, *Eastman Kodak Co.*, Rochester, N. Y.

The manufacture of motion picture film may well be studied from the point of view of the research man, the technical man, the manufacturer, the machine designer, and the personnel man; the efforts of all of whom must be coördinated to produce motion picture film successfully.

The fundamental requirements of manufacturing, after the emulsions and support formulas have been worked out, are cleanliness and uniformity. These are only to be obtained by a careful elimination of dirt at the source, an elaborate system of tests, and meticulous control of all processes. The flow of materials should approach as nearly as possible the ideal of continuous production.

The raw materials used are cotton linters, sulfur, sodium nitrate, camphor, and solvents for the nitrate base; cotton linters, acetic anhydride, acetic acid, triphenyl phosphate, and solvents for safety base; and hides, silver, nitric acid, potassium bromide, and sensitizing dyes for the emulsions. The nitration and acetylation of cellulose require more careful control of the original cellulose and

of the conditions of reaction than is necessary for other purposes, but otherwise the standard practice is followed.

In making the "dope," the cellulose ester, plasticizer, and solvents are carefully mixed in large mixers, with continuous filtration.

The coating or casting is carried out on large drums or wheels many feet in diameter and up to approximately five feet in width. With some systems, flexible metal bands are used in place of wheels. The coating surfaces are carefully polished and plated in order to give a smooth surface to the film support. A current of warm air is passed around the periphery of the drum in order to evaporate the solvents from the "dope," after which the film support is stripped from the wheel and subjected to further treatment, such as subbing, tinting, further drying, *etc.* The subbing is necessary in order to make sure that the gelatin emulsion will adhere to the film base.

The simple processes of emulsion making are well known, and the special details can not be discussed in the present paper; but uniformity is here attained, as in other parts of the manufacture, by carefully testing all raw materials and rigidly controlling all the details of the process, demanding, as well, years of experience on the part of the emulsion maker.

The emulsion coating operation is carried out by passing the film support, subbed side down, under a roller partly immersed in a pan of melted emulsion. The speed of coating and the temperature of the emulsion govern the thickness of the emulsion coating. Immediately after the coating, the emulsion is chilled to set it in place, and then dried under carefully controlled humidity, temperature, and air-velocity conditions, by passing the film in festoons through a long tunnel drier. The air used in drying the emulsion must be controlled as to relative humidity within a very small range if best results are to be obtained, since the speed of emulsions is sensitive to changes in moisture content.

The slitting and perforating of a film should also be carried out under controlled humidity conditions. The slitting is done by revolving knives, equally spaced above and below the film, to get a shearing action, the upper knife having a keen razor edge, and the lower knife a sharp square edge. The perforating is done by punches and dies so accurately made that the punches can not be inserted in the dies by hand without injury, although when clamped in the machines, they go in and out thousands of times without appreciable wear. Each punch consists of eight punching members and eight positioning members. The positioning members have tapered ends and fit the holes previously punched so as to position the film exactly for the next set of holes to be made.

The wrapping, storing, and shipping of the film are carefully controlled, and every endeavor is made to see that the customer receives the film under the best conditions for use.

"Stability of Motion Picture Films as Determined by Accelerated Aging;" J. R. Hill and C. G. Weber, *National Bureau of Standards*, Washington, D. C.

Motion picture film of the safety type shows great promise as a material upon which to preserve records of permanent value, according to tests made at the National Bureau of Standards. This type of film, having a base of cellulose acetate, is designed for use where the highly combustible film of the ordinary theater type, cellulose nitrate, presents too great a hazard from fire and explosion. In addition to its safety features, it appears to have the additional advantage of

being much more lasting. Both types of film were studied by determining the effects of various accelerated aging treatments upon samples of new film. Samples of old nitrate were tested also to determine their condition after natural aging.

The most satisfactory accelerated aging treatment found consists in heating the film in a dry oven, at 100°C., a test employed to find the relative stability of record papers. The films were tested for physical and chemical properties before and after oven-aging tests of various durations, and changes in the properties noted. High retention of folding endurance and viscosity, and small increase in acidity are considered indicative of stability. The acetate film was found to be excellent in these respects. Large losses in folding endurance and viscosity, plus large increases in free acid in the material characterized the changes in nitrate under the heat test. Its poor stability was further indicated by rapid change of resistance to an ordnance test used to determine the condition of smokeless powder.

The cellulose acetate film withstood oven-aging for 120 days without serious chemical or physical changes, while the nitrate film deteriorated beyond usefulness after 10 days under the same conditions. The acetate appears to have lasting qualities comparable to those of permanent-record papers of high quality, and the optimal atmospheric conditions for the preservation of paper records are suitable for this film. Nitrate film is perishable, and its deterioration is greatly accelerated under warm, moist conditions. The preservation of valuable nitrate film is a complicated problem involving both elaborate fire protective measures and air-conditioning.

"Care of Slide-Films and Motion Picture Films in Libraries;" C. G. Weber and J. R. Hill, *National Bureau of Standards*, Washington, D. C.

Reference libraries of the future may contain files of photographic films in addition to shelves of conventional books, if the present trend toward the use of films for recording and copying the printed word continues. Hence, it appears that librarians, long the custodians of our valuable books and papers, are to be confronted with the problems involved in the care of records on photographic films.

The film used for records is of the safety type. It is no more inflammable than books; hence it offers no new problems in fire protection. It is very stable chemically, and should be lasting if properly made and stored. However, the safety film is quite sensitive to moisture changes, and is brittle when dry. It is pointed out that satisfactory service requires that the moisture content be controlled by air-conditioning the storage rooms or vaults. The ordinary type of motion picture films have a base of cellulose nitrate which is highly combustible. The storage of this type of film presents difficult problems of fire protection, and should not be undertaken by anyone not entirely familiar with the problems.

"Fire Prevention in the Motion Picture Industry;" H. Anderson, *Paramount Pictures, Inc.*, New York, N. Y.

The subject of fire prevention in the Motion Picture industry is extremely broad, since the motion picture industry embraces practically every known fire prevention problem.

It is of the utmost importance, because of the combustible nature of motion picture film, the necessary consideration that must be given to safety of life in the operation of theaters, and the serious financial effect of the interruption of

studio operations by fire. It is further complicated by the extreme susceptibility of sound recording and reproducing equipment and of finished motion picture film to fire and water damage.

Motion picture exchanges under the Motion Picture Producers & Distributors of America, Inc., have had an amazingly excellent fire record, the lowest fire loss record of any industry in the United States. This is the result of the adoption of active fire prevention measures by the exchanges, as described in this paper. It is suggested that the Society of Motion Picture Engineers interest itself in active fire prevention work in the industry, and that individual motion picture engineers keep fire prevention in mind in connection with their work, whether it be operation or design.

In design, where possible, non-combustible materials should be included, and the construction should be such that the apparatus is protected as far as possible against damage by the water or chemicals used for fighting fire.

The chemistry of fire extinguishing is discussed, as also the various types of fire apparatus. The principal types of fire extinguisher are described, and their effectiveness and defects brought out particularly with respect to their application to the motion picture industry. A description of experiments made with a new type of high-pressure spray system is given.

The standard methods of fire prevention in laboratory, exchange, and theater are discussed, and a detailed description is given of the fire problem in motion picture studios. The special apparatus necessary due to the severity of the problem, and the organization and procedure of the studio fire department are described.

While the National Fire Protection Association and insurance companies have established standard requirements for the installation of fire equipment in projection rooms, exchanges, and in connection with sound equipment, no set of instructions has ever been prepared for the benefit of motion picture projectionists at time of fire. The problem constantly arises as how to handle a fire properly in the projection room. It is recommended that the SMPE adopt a standard set of instructions which will tell the projectionist exactly what to do in case of fire.

A motion picture showing various fire-preventing devices, and fire apparatus in action in a motion picture studio will be shown at the conclusion of the paper.

"The Projection of Lenticular Color Films;" J. G. Capstaff, O. E. Miller, and L. S. Wilder, *Eastman Kodak Co.*, Rochester, N. Y.

In the projection of lenticular color films a large portion of the incident light is lost be absorption in the tricolor filters. To determine the feasibility of satisfactorily showing these films in large theaters, an experimental projector was set up embodying the few simple changes in standard theater equipment that were necessary to obtain the required large increase in screen illumination.

Successful demonstrations with the apparatus at *Loew's Rochester Theater* at Rochester and the *Center Theater* at New York have proved that it is quite possible to secure enough screen brightness to give a satisfactory showing of the lenticular films in the majority of theaters.

The principal changes made in the standard projection apparatus in order to obtain the greatly increased illumination were as follows:

(1) *Increased Relative Aperture.*—By substituting an $f/1.6$ projection lens for the $f/2.4$ lens commonly used, and by increasing the working relative aperture of

the 65-ampere high-intensity reflector arc so as to take full advantage of the increased aperture of the projection lens, it was possible to get 2.25 times the screen illumination obtained with the regular equipment.

(2) *Reduction of the Shutter Loss.*—A further increase was obtained by the use of a quicker pull-down and a corresponding reduction in the angle of the shutter blades; this may not, however, be feasible in practice.

(3) *Increased Filter Transmission.*—As a result of numerous practical tests it was found to be possible to increase the transmission of the tricolor projection filters by 33 per cent, without undue loss of color values.

(4) *Lower Print Density.*—The excellent tone reproduction obtained in the process, together with a modification of the optics of the lenticular film, makes possible a substantial lowering of the print density. The resultant increase in the brightness of the projected image amounts to some 25 per cent.

The large increase in the radiant energy directed onto the film has made it necessary to employ a heat filter in the condenser system.

Refinements in the present system are expected to produce additional small increases in illumination, and it is believed to be possible to develop other special equipment to take adequate care of the few (special) cases where it is necessary to project upon an unusually large screen.

"Effect of Lens Aberrations on Image Quality;" W. B. Rayton, *Bausch & Lomb Optical Co.*, Rochester, N. Y.

Lenses are used to form images for two principal purposes: first, to produce the most accurate record possible of the original object; and second, to produce a pleasing effect. The character of the image formed by a lens depends upon diffraction and upon the residual aberrations left after the designer and the manufacturer have done their best. For pictures of the first type it is desirable that aberrations be reduced to a minimum, but for pictures of the second type they are very often deliberately employed to produce desired effects. In motion picture projection, lenses of the first class are doubtless always desired. In motion picture photography, some attention has been given to achieving special effects by deliberately introducing aberrations into the lens.

Among the many aberrations that afflict lenses, one of the most important is chromatic. Since, in general, only two colors can be brought to a common focus, some thought has been given to the question of what two colors are best to choose to meet the requirements of various kinds of lighting and different types of sensitivity of the emulsion. Recent experiments indicate that for a combination of particular interest in motion picture photography, namely, incandescent lighting and super-pan emulsion, no significant difference in performance is detectable among lenses of 12-inch focus or less, depending upon whether the two colors chosen for chromatism are yellow and violet, or red and violet.

"Mercury Arcs of Increased Brightness and Efficiency;" L. J. Buttolph, *General Electric Vapor Lamp Co.*, Hoboken, N. J.

The low brightness, 15 candles per square-inch, of the Cooper-Hewitt mercury arc, while an asset in industrial illumination, has prevented possible applications of the lamp where high brightness and, consequently, small source areas are essential for use with reflectors and refractors, and are valuable for use where space is at a premium. The Cooper-Hewitt quartz mercury arc represented an increase of 500 to 1000 candles per square-inch, which permitted compact

reflectors but still meant too large a source for satisfactory control by optical means. This brightness has still been so low compared with the 10,000 foot-candles per square-inch possible with incandescent lamps and the 100,000 characteristic of the crater of the carbon arc, that little serious thought has been given to the mercury arc for projection or for long-range floodlighting work.

The recent development of so-called super-high-pressure mercury arcs has now opened up some of these possibilities. By designing a quartz mercury arc to operate at mercury vapor pressures of 20 to 30 atmospheres instead of the 1 atmosphere characteristic of the older high-pressure arcs, brightness of the order of 5000 candles per square-inch is attained in air-cooled lamps. By operating water-cooled arcs at higher pressure, brightnesses of 100,000 to 250,000 candles per square-inch have been attained during rather short lamp lives. Of the possibilities ranging in rating from 50 to 10,000 watts, only one unit thus far has been standardized for manufacture in the United States.

The 85-watt, type *H-3* mercury lamp may be thought of as a small version of the type *H-1*, 400-watt and the type *H-2*, 250-watt mercury lamp standardized during the past few years. It is operated from a similar reactive transformer providing 440 volts for starting and 250 volts at the arc terminals, at a normal arc current of 0.4 ampere. It is rated at 35 initial lumens per watt in the arc and for a 500-hour life. The quartz tube of the arc proper is enclosed in an outer insulating bulb of ordinary glass, which limits the short-wave end of the spectrum to about 320 μm. Through the visible and near-ultraviolet range the spectral distribution is similar to that of other high-pressure mercury arcs except for the unusual intensity of the 365 μm lines.

The effective dimensions of the light-source or arc proper are about 0.6 by 0.15 inch, but the discharge is of the constricted type, giving a higher maximal brightness than the dimensions would indicate in calculation.

This arc is of the oxide-coated electrode type, designed only for a-c. operation. Since the light output follows approximately the arc current, its intensity is variable; and although the flicker is not noticeable directly, it is such as to produce stroboscopic effects on moving objects, and may be a limitation in photography or in projection where motion is involved.

It is believed that the high intensity of the 365 μm lines and the high brightness of the source may permit application of the lamp to certain of the more highly specialized lighting problems in the motion picture industry.

"Trick and Process Cinematography;" J. A. Norling, *Loucks and Norling Studios*, New York, N. Y.

Process photography, which is the broad classification given to all branches of special and trick cinematography, plays an important part in making today's motion picture. Many articles have appeared relating to this subject, but, unfortunately, most of them have been devoted only to a discussion of the importance of this branch of photography and very few writers have divulged any of the details of the methods employed. This paper sets forth in general the underlying procedure in the various branches of the art, and treats many phases thereof in sufficient detail to be fully informative.

The branches of process photography disclosed include: transitional effects, such as dissolves and wipes; matte shots; simple and intricate multiple exposures; composites and montages; animated titles and presentation effects;

combined drawing and actual photography; optical trick printers and cameras; miniature projection background process; problems in making dupe negatives by projection, dodging, *etc.* Important steps are described and illustrated, and special apparatus will be shown and their essential functions and operation described.

"Report of Standards Committee;" E. K. Carver, *Chairman.*

Since the last report of the Standards Committee, drawings have been completed for a new booklet, changing the form of the drawings to conform to the American Standards Association specifications.

No fundamental changes have been made in the dimensions, but the 16-mm. sound-film drawing has been changed to a slight extent to conform better to current practice.

A sub-committee is at work on the question of a single type of perforation for both negative and positive, and the early proposal that a perforation having the dimensions of the old negative perforation and the shape of the new positive perforation be adopted as standard has been brought up again, due to the difficulty of accomplishing the adoption of the present standard perforation by the users of negative film.

The proposal made by the German Standards Association that 16-mm. film spools be standardized with square holes on each side has been referred to the subcommittee on sub-standard film, and a report has been received from them.

The standardization of 2000-foot reels is still under discussion.

"The Performance Record of an Automatic Recording Densitometer;" C. M. Tuttle and M. E. Russell, *Eastman Kodak Co.*, Rochester, N. Y.

A recording physical densitometer designed to read strips from the type II*b* sensitometer was described recently in *J. Opt. Soc. Amer.* This instrument has been in service in the sensitometric department of the Kodak Research Laboratories for about one year, during which time it has been operated steadily. Approximately 100,000 sensitometric strips have been read thus far. The instrument is capable of an output of about 550 strips per day.

Experience has shown that more repeatable results are attained with this instrument than by routine, visual methods. Comparative data accumulated in an experiment lasting several months will be presented, along with a time-study of the two methods of densitometry.

Certain features to be changed in the design of a new instrument will be discussed. The new instrument will be improved both as to ruggedness and speed.

The advisability of using devices of this nature in a release print laboratory will depend upon a number of factors, such as initial cost, quantity and quality of output, and ease of maintenance.

"A Developing Machine for Sensitometric Work;" L. A. Jones, M. E. Russell, H. R. Beacham, *Eastman Kodak Co.*, Rochester, N. Y.

The sensitometric testing of photographic materials requires that the testing laboratory be able to obtain the same results, with a high degree of precision, for identical samples of material, although the individual tests may necessarily be made at widely differing times. This necessitates that all the factors tending to influence the results be held constant over long periods of time. The present communication deals specifically with one particular phase of the sensitometric process, namely, the development of the samples.

The developing machine described is designed particularly for a laboratory in which a relatively large volume of sensitometric work must be done. It accommodates sixty strips positioned vertically on six metal racks which can be lowered into the developing solution simultaneously, and removed either simultaneously or individually, so that different development times may be given conveniently to different parts of the load.

The circulation of the developing solution across the face of the exposed material is sufficiently rapid so that further increase in violence of agitation produces little if any increase in the rate at which the latent image is converted into metallic silver. This circulation is of two general types: A relatively slow but uniform movement of the developer in the vertical direction is attained by a motor-driven propeller which forces the developer down into a well external to the main tank from the lower end of which it spreads out beneath a perforated false bottom in the tank and rises throughout the body of the tank, flowing back again into the top of the well. Much more violent agitation is accomplished by a set of vertical paddles which move back and forth close to the exposed surfaces. Both agitating elements are driven by a synchronous motor, thus assuring the same rate of circulation at all times.

The entire developing machine is water-jacketed with thermostatically controlled constant-temperature water, held at a temperature of 65° ± 0.1°F.

A careful analysis of the results obtained with the machine has been made, showing that the circulation throughout the body of the tank is so nearly uniform that the results are not influenced by (*a*) whether the heavily exposed end of the sensitometric strip is up or down, (*b*) the position of the strip within the tank, (*c*) or whether a complete or partial load of strips is developed at one time. Results indicate also that the agitation is of sufficient violence that the rate of conversion of the latent image into metallic silver is at or near the maximum attainable. The uniformity and reproducibility of development attained by using the machine are very markedly superior to that attainable with any type of hand- or machine-rocked tray with which we have had experience, and the use of this machine marks a very definite advance in the precision with which sensitometric values may be established.

"Some Aspects of Reduction Printing;" G. Friedl, Jr., *Electrical Research Products, Inc.*, New York, N. Y.

Information recently obtained by the Standards Committee indicates that various groups of dimensions are used for the picture image on 16-mm. reduction prints. These data are set forth and the different conditions are reviewed that may exist in the projection of prints reduced from 35-mm. negatives made with the present standard camera aperture of 0.631 × 0.868 inch, as well as "old silent" films. Some consideration is given also to variables introduced by shrinkage.

"The Influence of Sprocket-Hole Perforations upon the Development of the Adjacent Sound-Track Areas;" J. G. Frayne and V. Pagliarulo, *Electrical Research Products, Inc.*, Los Angeles, Calif.

An unmodulated sound-track when developed shows 96-cycle modulation. The effect is a maximum at the edge of the sprocket holes and diminishes exponentially for a distance of approximately 30 mils into the sound-track. A film modulated with a constant frequency shows 96-cycle amplitude and frequency modulation over the same area. Both effects are introduced principally during process-

ing of the film. A film having no sprocket holes on the sound-track side is entirely free of these effects.

APPARATUS PAPERS

"A New Type of Peak Reading Volume Indicator;" F. L. Hopper, *Electrical Research Products, Inc.*, New York, N. Y.

A new type of volume indicator is described that meets the requirements of sound recording. Its advantages are: indication of peak values of voltage; full indication for sounds of short duration; adjustment for slow restoring action for greater ease of reading; the device may be given the same sensitivity-frequency characteristic as that of the light-valve; use of a well damped long-scale indicating type of meter.

"A Neon Type Volume Indicator;" S. Read, Jr., *RCA Manufacturing Co., Inc.*, Camden, N. J.

A number of gaseous discharge lamps of the neon type have been used to indicate instantaneous peak amplitudes of audio-frequency voltages. When the instantaneous value of the signal voltage increases to the value at which the first lamp is adjusted to discharge, the lamp starts to glow. When the voltage is still further increased, additional lamps begin to glow as their discharge values are reached. As the instantaneous voltage decreases the lamps are extinguished in the reverse order.

Such a device provides a definite indication of the peak value, even though of extremely short duration. Due to the persistence of vision, such extremely short peaks are not lost, although voltages sustained over longer periods produce brighter glows. Only one-half of the voltage wave actuates the neon lamps; therefore, either positive or negative peaks may be noted. Any portion of the scale may be expanded or compressed as desired. Radiotrons of the Acorn type are used so as to achieve a compact unit.

The device is compared with volume indicators of other types, and some of its unique circuits are discussed. Diagrams and performance curves are included.

"A Neon Tube Oscilloscope as a Utility Instrument for the Projection Room;" F. H. Richardson, *Motion Picture Herald*, New York, N. Y., and T. D. Hover, *Ohio Theater*, Lima, Ohio.

A neon type of rotating mirror oscilloscope is described intended for routine use by projectionists to aid in eliminating noise due to microphonic tubes, improperly meshed gears, *etc.* The parts may be either purchased or built by the projectionist.

"Recent Developments of High-Intensity Arc Spotlamps for Use in Motion Picture Production;" E. C. Richardson, *Mole-Richardson, Inc.*, Hollywood, Calif.

In order to utilize high-intensity carbon arcs more effectively as sources of illumination for photographic purposes, two newly designed high-intensity arc spotlamps have been developed. Improvements have been incorporated in the design which particularly adapt the lamps for use under modern photographic conditions, particularly in the production of colored motion pictures, where uniformity of spectral distribution and intensity are vital factors.

In the design of the arc mechanism used in these lamps, vital improvements are: (*1*) increased rotational speed of the positive carbon; (*2*) continuous non-

intermittent feeding of both positive and negative electrodes; (*3*) rapid-action positive and negative manual adjustments.

The paper describes in detail the application of "Morinc" flat corrugated lenses to the new equipment, and illustrates, by means of graphs, the light distribution attained for various beam divergencies. The new equipment has had sufficient practical application in motion picture production to have proved its worth in photographing under both normal and Technicolor production.

"Film-Editing Machine Embodying Optical Intermittent Projection;" J. L. Spence, *Akeley Camera, Inc.*, New York, N. Y.

The Akeley-Leventhal editing machine is built around the Leventhal two-stage optical compensator, which substitutes an optical intermittent for the usual mechanical intermittent, thereby enabling the film to travel uninterruptedly past the projection aperture.

A single small piece of plate glass rotating once per picture cycle in synchronism with the film-feeding sprocket takes the place of the usual intermittent claws or intermittent sprocket. The system is a two-stage one, and should not be confused with single-stage compensators which make one-half revolution per picture cycle.

It is possible with this equipment to throw into synchronism a sound-track film and a picture film while both films are running. A simple selective means is provided for running sound-film only, picture film only, or both together. Reels 2000 feet long may be run without adjustment. A 6-inch picture having an illumination of 10 foot-candles is attainable.

Two motors are used for driving the machine, one constant- and one variable-speed. The simple temporary splicer employing the cellophane tape is built into the machine.

"New Recording Equipment;" D. Canady and V. A. Wellman, *Canady Sound Appliance Co.*, Cleveland, Ohio.

A new sound-film recorder for studio or portable use is described. Three flywheels in addition to a non-resonant drive sprocket filter enable the machine to operate satisfactorily on power lines of poor regulation. Tests have proved that violet surges on the power supply line have no noticeable effect upon the linear film speed. The recorder is unusually quiet in operation. It can be used on the set if need arises. Mention is made of recording lamp improvements, and a noise-reduction unit for operation in connection with glow lamps is described. A self-contained semiportable recording amplifier is also discussed.

"An Improved Reel-End Alarm;" D. Canady and V. A. Wellman, *Canady Sound Appliance Co.*, Cleveland, Ohio.

Scratching and mutilation of release prints by mechanical reel-end alarms in projectors are touched upon, and a description of an improved indicating device is given. Use is made of a light-source and a photoelectric cell. The light-rays from the light-source pass at a tangent to, or across, the film. When the point of tangency has been reached, the film that previously obstructed the light-ray allows the ray to reach the photoelectric cell, which, in turn, actuates the signalling device. The device is positive in action and automatic in operation. Nothing mechanical touches the film.

"Three-Wire D-C. Supply for Projection Arcs;" C. C. Dash, *The Hertner Electric Co.*, Cleveland, Ohio.

The introduction of the non-rotating, high-intensity, low-voltage, d-c. arc has

made it desirable to use a d-c. supply of as low voltage as practically possible. The auxiliary projection equipment, such as the spotlamp, dissolver lamps, and effect machines, are still equipped with arc lamps requiring 55 to 65 volts across the arc. In order to obtain the benefits of the new lamps using the Suprex type of carbon, it is desirable to have a d-c. source of the proper voltage for each type of lamp to be used.

Two flat-compounded generators may be connected in series so as to have the voltage of each generator available or the combined voltage of the two in series.

There has been developed a double-voltage motor-generator arranged so that low voltage is available for the non-rotating high-intensity projection lamps, and also double the voltage of the single generator for the auxiliary equipment. The design of this type of motor-generator may be such that changing the load on either generator does not affect the output voltage of the other generator. Performance curves of this two-unit motor-generator set demonstrate the steadiness of the output voltage with changes of load.

"A Demonstration Triode for Visualizing Electronic Phenomena;" F. E. Eldredge and H. F. Dart, *Westinghouse Lamp Co.*, Bloomfield, N. J.

To augment theoretical discussion with a practical demonstration, a new type *WL-787* triode has been developed for visualizing the electronic effect when changes are made in the grid and plate voltages of a vacuum tube.

The filament consists of several parallel oxide-coated wires, all of which are located in one plane so that the plate current will be uniformly distributed. The anode is the fundamental flat plate mounted parallel to the plane of the filament. The grid is a fairly open and conventional structure, mounted between the filament and the plate. The side of the anode facing the grid and the filament is coated with willemite, which shows a bright greenish fluorescence when bombarded by electrons of the plate current. A pronounced and clearly visible glow occurs at all points where the electrons strike, resulting in a definite pattern of the grid upon the plate. Plate size is such that the action can be observed by everyone in a room of reasonable size. Either alternating or direct current may be used to heat the filament and to supply the voltages for the grid and plate.

The demonstration triode, therefore, becomes a tool that can be used in the classrooms of universities, colleges, and technical schools to supplement the theoretical discussions. It is useful also for demonstrating visually any vacuum tube phenomena depending upon the fluctuation of the grid voltage to vary the plate current.

JOURNAL

OF THE SOCIETY OF

MOTION PICTURE ENGINEERS

Volume XXVII **NOVEMBER, 1936** **Number 5**

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JOURNAL
OF THE SOCIETY OF
MOTION PICTURE ENGINEERS

Subscription to non-members, $8.00 per annum; to members, $5.00 per annum, included in their annual membership dues; single copies, $1.00. A discount on subscriptions or single copies of 15 per cent is allowed to accredited agencies. Order from the Society of Motion Picture Engineers, Inc., 20th and Northampton Sts., Easton, Pa., or Hotel Pennsylvania, New York, N. Y.

Published monthly at Easton, Pa., by the Society of Motion Picture Engineers.

Publication Office, 20th & Northampton Sts., Easton, Pa.

General and Editorial Office, Hotel Pennsylvania, New York, N. Y.

Entered as second class matter January 15, 1930, at the Post Office at Easton, Pa., under the Act of March 3, 1879.

See p. 600 for Technical Committees

KINEMATOGRAPHIC EXPERIENCES*

ROBERT W. PAUL**

Summary.—*The first commercial showing of motion pictures in England was probably made by two men with six Edison peep-show Kinetoscopes installed in a shop in Old Broad Street, London, in 1894. Six duplicates of these devices (which had not been patented in England) were built in that year by Paul, and sixty machines during 1895. A camera having a cam-driven intermittent movement was also built in 1895 from a design by Paul and Acres, the latter an English photographer. Printing and developing equipment were developed to process the films made with the camera. In 1895 a second camera was constructed in which intermittency was achieved by means of a modified Geneva stop. The public interest shown in the Kinetoscope and its inadaptability for projection stimulated Paul late in 1895 to design a projector having an intermittent movement consisting of a seven-toothed star-wheel.*

Many interesting experiences in making and exhibiting pictures during 1896 and subsequent years are described. The first motion picture studio in Great Britain was designed and built by Paul in 1899 at Muswell Hill, North London. Trick films and scientific pictures were made there as well as other subjects. The project was closed about 1910 because it was regarded as too speculative as a side-line to instrument making.

My first contact with animated photography occurred by chance in connection with my business, as a manufacturer of electrical and other scientific instruments, which I had started at Hatton Garden, London, in 1891. In 1894 I was introduced by my friend, H. W. Short, to two men, George Georgiades and George Tragedes, who had installed in a shop in Old Broad Street, E. C., six Kinetoscopes, bought from Edison's agents in New York. At a charge of twopence per person per picture, one looked through a lens at a continuously running film and saw an animated photograph lasting about half a minute. *Boxing Cats*, *A Barber's Shop*, and *A Shoeblack at Work* were among the subjects, and the public interest was such that additional machines were urgently needed. Finding that no steps had been taken to patent the machine, I was able to construct six before the

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* Requested and recommended for publication by the Historical Committee. Obtained with the coöperation of E. A. Robins, who was one of the early assistants of Mr. Paul.

** Cambridge Instrument Co., Ltd., London, England.

end of that year. To supply the demand from travelling showmen and others, I made about sixty Kinetoscopes in 1895, and, in conjunction with business friends, installed fifteen of them at the exhibition at Earl's Court, London, showing some of the first of our British films, including one of the boat race and derby of 1895. The sight

FIG. 1. Rotary printer.

of queues of people, waiting their turn to view them, first caused me to consider the possibility of throwing the pictures upon a screen. Moreover, it had become evident that the weight of the Kinetoscope and the difficulty, at that time, of recharging its accumulators, militated against its extensive use.

Users of my Kinetoscopes shortly after that were refused supplies of films by the Edison agents, so I was forced to produce new subjects. Film stock, with a matte celluloid base, was procurable from Blair, of

St. Mary Cray, Kent. For negatives, Kodak film having a clear base was preferred. In Birt Acres I found a photographer willing to take up the photography and processing, provided I could supply him with the necessary plant, which I did early in 1895. For perforating the film I made, for use in an ordinary fly-press, a set of punches, 32 in number, made to the Edison gauge and fitted with pilot pins. We had no information to guide us in designing a camera, but I worked out an idea due to Acres. The film was drawn by a continuously

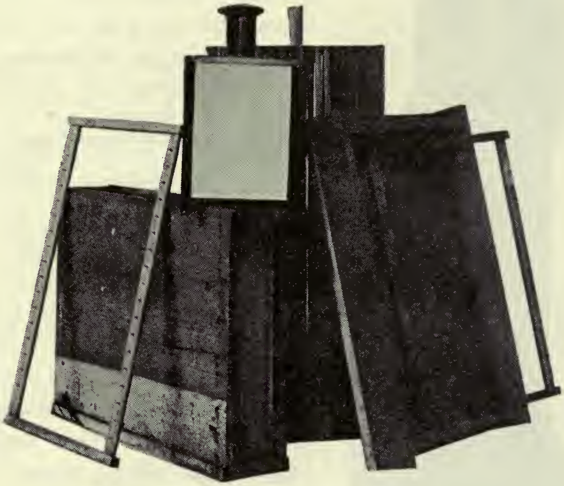


FIG. 2. Developing racks and drying drums.

running sprocket from an upper spool, past the light-opening, or gate, to another spool below, and was kept under a slight tension. A marginal clamping plate, intermittently actuated by a cam, held the film stationary in the gate during each exposure. A shutter, whose opening synchronised with the cam, revolved between the lens and the gate. In our first trial we failed to get a picture on Blackfriars Bridge only because we forgot, in our excitement, to attach the lens.

Our printer (Fig. 1) was of the rotary type, consisting merely of a sprocket over which the positive and negative films passed together, behind a narrow slot illuminated by a gas jet. The sprocket was turned by hand at a speed judged by the operator, who inspected the negative as it travelled past a beam of red light. For development, a

40-ft. length of film was wound upon a birch frame with spacing pegs. Horizontal or vertical troughs held the solutions and washing water. At first drying was done in festoons, but a little later on light wooden drums (Fig. 2). Our first successful Kinetoscope film was taken in February, 1895. We took a fair number of subjects, such as *Rough Seas at Dover,** *An Engineer's Smithy,* and some comic scenes, in addition to the two topical films already mentioned. A number of such films, joined as endless bands forty feet long, were exported, more especially to the United States and to Germany, but I do not believe that our total output for the year exceeded ten thousand feet.

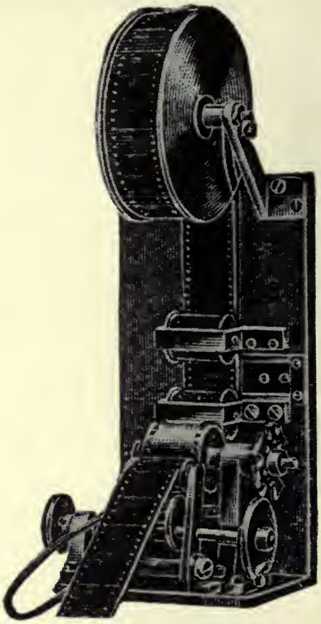


FIG. 3. Star-wheel intermittent projector (Feb., 1896).

A POSITIVE INTERMITTENT MOTION

The intermittent motion in our first camera was, as I pointed out to Acres, not well suited to give accurate spacing, and the pictures compared unfavorably in that respect with the original Edison films. So soon as the camera was put into use I therefore proceeded to make a second, with which many of our 1895 films were taken. In it I adopted a modification of the familiar Geneva stop, as used in watches, to give an intermittent motion to the sprocket. Because the 14-picture sprocket of the Kinetoscope had too great inertia, I made one of aluminium, one-half the diameter.

My first projector (Fig. 3) is described in *The English Mechanic* of February 21 and March 6, 1896. It was intended to be sold at a price of five pounds, and to be capable of attachment to any existing lantern. The seven-toothed star-wheel was driven by a steel finger-wheel which acted also as a locking device during the period when

* This film was included in the program shown at Koster & Bial's Music Hall, New York, on April 23, 1896, when the Armat *Vitascope* was used to project the pictures.[1]

the shutter was open. The latter was oscillated behind the gate by means of an eccentric, and a hand-operated safety shutter was provided. Four light spring pads pressed upon the corners of the film, which was fed out into a basket. A fault, which I ought to have foreseen, was the unsteadiness caused by the inertia of the spool of films, and it became necessary to insert the films, 40 or 80 feet long, singly. So this model, by means of which I first saw a motion picture upon the screen, was promptly scrapped.

The next step (Fig. 4) consisted in duplicating the intermittent

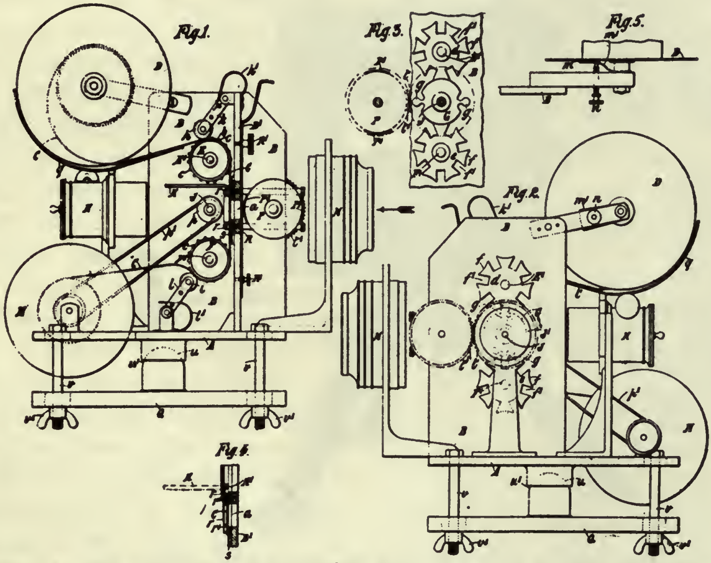


FIG. 4. Second model of intermittent projector (Brit. Pat. No. 4686, March 2, 1896).

sprockets, the film near the gate being kept more or less taut between them.[2] At that time the likelihood of shrinkage of the film was not realized. The machine had a revolving shutter, in the form of a horizontal drum cut away on two opposite sides, and a rewind spool was provided, driven by a slipping belt. A large handwheel was belted to a small pulley upon the fingerwheel spindle, the latter being coupled to the shutter spindle by spur gears. After a few of these projectors had been put into operation the need for larger spools, to contain a series of films, became evident. So additional sprockets were arranged to give continuous feed above and below the intermittent sprockets.

The projector was furnished complete with lantern and illuminant, either arc or limelight. This model was used in all my earlier public demonstrations and more than 100 of them were produced, many being exported to the Continent and to the United States. One of these projectors, used at the Alhambra Theater, is preserved in the Science Museum, London, together with a camera (Fig. 5) made in 1896, having a precisely similar driving mechanism. Both pieces of appara-

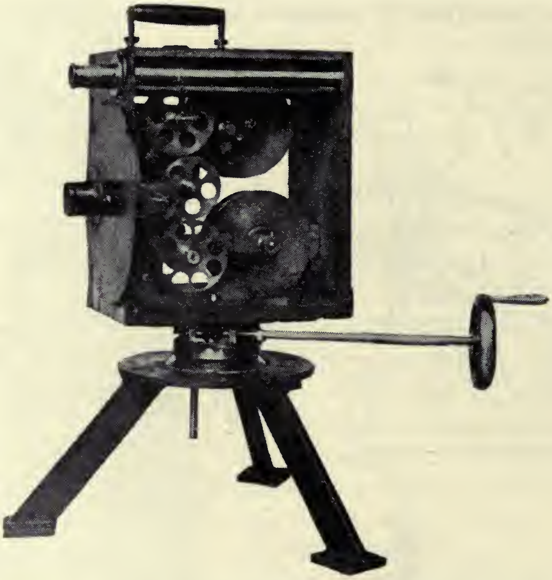


FIG. 5. Paul's kinematograph camera (1896). One of the first successful types to be introduced in England; used for filming Queen Victoria's Jubilee in 1897, for which purpose a special stand for revolving the camera was designed.

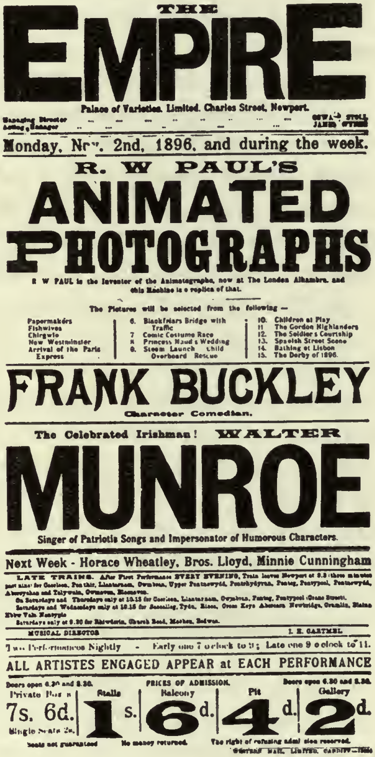
tus were decidedly noisy, but as the projector was then usually placed at the back of a stage, behind a translucent screen, this disadvantage was not regarded as serious.

EARLY DEMONSTRATIONS

I named the projector the *Theatrograph*, under which title it formed an item in an entertainment at Finsbury Technical College, London, on February 20, 1896. A week later the machine was shown at the Royal Institution. There the pictures were seen by Lady Harris,

whose husband was a leading impresario, responsible for managing the Theater Royal, Drury Lane, and a big spectacle at Olympia. Next morning Sir Augustus Harris telegraphed me to meet him at breakfast, and proposed that a projector be installed at Olympia on sharing terms. He added that he had recently seen animated photographs at Paris, and prompt action was necessary as he was sure that the popular interest would die out in a few weeks. Though I knew nothing of the entertainment business I agreed to install the machine in a small hall at Olympia in March, 1896, and was surprised to find my small selection of films received with great enthusiasm by the public, who paid sixpence to view them.

The first public exhibition of the Lumière cinematograph in England took place, also on February 20th, at the Polytechnic in Regent Street, and the results were then superior in steadiness and clearness to my own. To compete with that machine, as shown at the Empire Theater in Leicester Square, the Manager of the Alhambra asked me to give a show, as a ten-minute item in the program, with my Theatrograph, which he renamed the *Animatographe*. This engagement was for two weeks, beginning March 25th, but actually continued for about two years. The salary, or fee, was at the rate of eleven pounds for each performance, far more than I had expected. In April, the Alhambra manager, Mr. Moul, who wisely foresaw the need for adding interest to wonder, staged upon the roof a comic scene called *The Soldier's Courtship*, the 80-foot film of which caused great merriment. The climax came in June, with the presentation of



THE
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PHOTOGRAPHS

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Papermakers
Fishwives
Chirgwin
New Westminster
Arrival of the Paris Express
6. Blackfriars Bridge with Traffic
7. Comic Costume Race
8. Princess Maud's Wedding
9. Steam Launch Child Overboard Rescue
10. Children at Play
11. The Gordon Highlanders
12. The Soldier's Courtship
13. Spanish Street Scene
14. Bathing at Lisbon
15. The Derby of 1896.

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FIG. 6. Section of program at Empire Theater, Newport, England, beginning Nov. 2, 1896.

the Prince's derby, won by Persimmon. The incidents connected with its taking were fully recounted in an illustrated article in *The Strand Magazine*, and His Royal Highness came to see the film. It is a little difficult today to visualize the mad enthusiasm of the closely packed audience, which demanded three repetitions of the film, and sang *God Bless the Prince of Wales*, while many stood upon their seats.

During the summer of 1896 we were busy getting new subjects, some of the leading entertainers being quite willing to participate in the scenes, often without payment. Further, I equipped my friend, Short, with a camera with which he took some interesting films in Portugal, Spain, and Egypt. Of these one of the most popular was taken from the interior of a cave near Lisbon, and showed enormous breakers which appeared to be about to overwhelm the spectators.

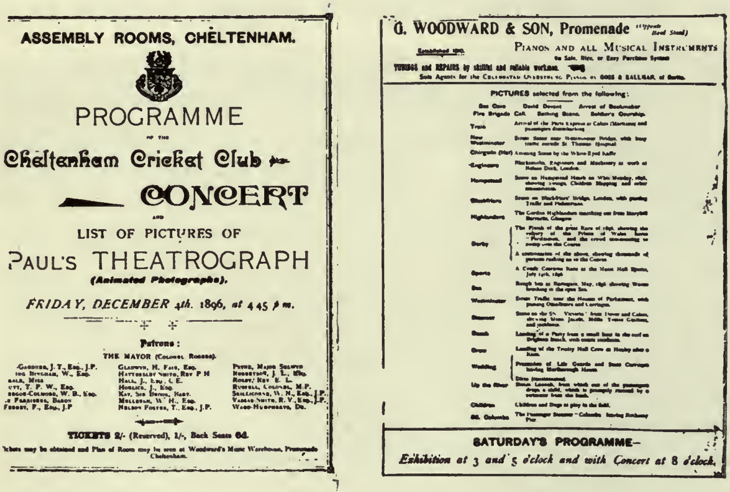
At this period the purchasers of many of my projectors worked them personally. Though we did our best to train lanternists and limelight operators to use the machine properly, their results were sometimes indifferent. Therefore, I attended in the evenings at many of the London music halls, the times of showing being carefully arranged in advance. This helped to maintain the reputation of the projector. I drove, with an assistant, from one hall to another in a one-horse brougham, rewinding the films during the drive. Figs. 6 and 7 are reproductions of sections of original programs of showings given at the Empire Theater, Newport, on Nov. 2, 1896, and at the Cheltenham Cricket Club on Dec. 4, 1896.*

SELLING PROJECTORS IN 1896

As a result of these demonstrations an extraordinary demand arose, first from conjurors and then from proprietors of halls, fair-ground showmen, and speculators who wanted exclusive rights for a territory. The first purchaser was David Devant, then with Maskelyne. The latter refused to join in the venture, but engaged Devant to perform with the machine twice daily at a salary, the projector being eventually used thus for two years. Devant also gave evening shows at private houses for a fee of 25 guineas. Through him I sold several projectors to Meliss, the Parisian conjuror, who converted one of

* The original programs were supplied to the Historical Committee by E. A. Robins, one of Mr. Paul's assistants at the time. Mr. Robins is now an official of Kodak, Ltd., Wealdstone, Middlesex, England.

them into a camera with which he took his first trick films. Another "mystery merchant," Carl Hertz, took a machine to South Africa in April, projecting the first animated photographs ever seen at sea, on board the S.S. *Norman*. Customers came from nearly every country, and beset the office with their interpreters, while each insisted upon waiting until a projector could be finished. Additional premises and assistants became necessary in order to provide instruction, which was sometimes rather difficult. Four Turks, speaking little English, came daily for weeks, put on their slippers, and prac-



ASSEMBLY ROOMS, CHELTENHAM.

PROGRAMME

Cheltenham Cricket Club

CONCERT

LIST OF PICTURES OF

PAUL'S THEATROGRAPH

(Animated Photographs).

FRIDAY, DECEMBER 4th. 1896, at 4.45 p.m.

Patrons:

THE MAYOR

TICKETS 2/- (Reserved), 1/-, Back Seats 6d.

G. WOODWARD & SON, Promenade

PIANOS AND ALL MUSICAL INSTRUMENTS

PICTURES selected from the following:

SATURDAY'S PROGRAMME—

Exhibition at 3 and 5 o'clock and with Concert at 8 o'clock.

FIG. 7. Section of program at Cheltenham Cricket Club, Dec. 4, 1896, of showing with the *Theatrograph.*

ticed. Finally they found that the attractiveness of night life in London had led to the complete exhaustion of their financial resources. A gentleman from Spain, anxious to return quickly, proved too impatient to learn how to center the arc light, and left with his projector, unboxed, in a cab. Arriving at Barcelona his first attempt at projection failed, whereupon the disappointed audience threw knives at the screen and wrecked the theater. He himself retired to serve a term in a Spanish prison. The court painter to the King of Denmark, sent over by his royal master to fetch a projector, also had trouble with the arc lamp and had to return for further instruction. Fortunately, such mishaps were rare. A little later the King of

Sweden and Norway sent his artist for a projector, with instructions that the maker was to accompany the projector and see it properly installed in the palace at Stockholm. This I did, I hope, to his satisfaction, and I was granted special facilities for getting Swedish pictures.

Here I must point out that these reminiscences are personal in character, and in no way an account of the industry or of the work of my competitors. From 1896 onward was a period of great activity, as may be judged from the number of patents for animated picture devices taken out in England, France, and Germany. In the 5 years, 1896 to 1900, these totalled 566, as against 63 for the five previous years.

EVENTS IN 1897

An outstanding event of 1897 was the Diamond Jubilee of Queen Victoria, with its magnificent pageantry of royalty and troops from all parts of the world, and the touching ceremony at the steps of St. Paul's Cathedral. Large sums were paid for suitable camera positions, several of which were obtained for my operators. I myself operated a camera perched upon a narrow ledge in the churchyard. Several continental kinematographers came over, and it was related of one that when the Queen's carriage passed he was under his seat changing film; and of another, that hanging on the railway bridge at Ludgate Hill, he turned his camera until he almost fainted, only to find, upon reaching a darkroom that the film had failed to start. An event of 1897 of a different character, which had serious repercussions, was the disaster at a Charity Bazaar at Paris, when 73 lives were lost in a fire at a kinematograph booth. The operator, using limelight with an ether saturator, attempted to recharge the latter, which exploded and set fire to the films which were loose in a basket. This sad event caused a widespread fear of similar disasters. I then produced a fireproof projector in which the film spools were enclosed in casings, the film passing through narrow slots to and from the mechanism. This machine had a four-picture sprocket actuated by a four-star Maltese cross; it was far more portable than my earlier projectors and was set upon a stiff tripod. In this year, after the Jubilee, the public interest in animated pictures seemed to be waning, in spite of the prompt presentation of topical films supplemented by a considerable output of amusing subjects. So soon as a topical film had been taken, all likely purchasers were informed by telegram or post,

and the darkroom staff, under J. H. Martin, worked hard to turn out prints, often continuously throughout the night. The work was not then specialized, any operator being ready to take or project pictures as occasion arose. The possibility of presenting upon the screen long films giving complete stories had yet to be exploited, and its realization formed a new phase in the development of the art.

WORK ON THE OPEN-AIR STAGE

To obtain space for taking subjects upon a more ambitious scale than was possible in London, I purchased a four-acre field at Muswell

FIG. 8. Enlargement from single frame, showing construction of miniature railway set.

Hill in North London. Pending the erection of a studio, to be described presently, work proceeded upon an open-air stage in an adjacent garden, where temporary buildings accommodated the processing operations. The stage was merely a platform having uprights for supporting a back-cloth, but it proved useful for many simple comic and dramatic pictures. Sometimes a picture combined scenes in natural surroundings with others upon the stage. For example, two divers were filmed, descending and ascending, close to Nelson's flagship, *H.M.S. Victory.* Between these views was inserted one on the stage, set with a back-cloth representing a wreck on which the divers worked, sending up treasure. We placed a large narrow tank

containing live fishes between the stage and the camera. Strange as it may now seem, the result appeared sufficiently natural to cause the Prince of Wales and Lord Rothschild, after seeing it upon the Alhambra screen, to ask me how it had been possible to photograph under water.

As an example of "model" work I recall a film (Fig. 8) representing a railway collision, of which the effect upon the screen was regarded very thrilling: A railway track runs alongside an embankment, below which is a lake bearing a yacht. A slow train comes along toward a tunnel and over-runs the signal. While the driver backs the train an express dashes out from the tunnel, and a collision occurs in which the trains are thrown down the embankment. This film had a large sale, and I was told that a great number of pirated copies appeared in America.

Fig. 9. Photograph of Paul's motion picture studio (1899).

In 1899 I sent out two cameras to the Boer War. One of them was lent to Colonel Beevor of the Scots Guards, one of the first regiments to leave, who was able to get about a dozen good films, including one of the surrender of Cronje to Lord Roberts. Nobody made pictures of actual fighting, though several operators obtained interesting

scenes on the lines of communication. To meet the demand for something more exciting, representations of such scenes as the bombardment of Mafeking and the work of nurses on the battlefield were enacted on neighboring golf links, under the supervision of Sir Robert Ashe, an ex-officer of Rhodes' force. These were issued for what they actually were, although I can not vouch for the descriptions applied to them by the showmen.

TRICK FILMS IN THE STUDIO

In 1899 we commenced work in a studio (Fig. 9) erected in a corner of the field. I believe it was the first in Great Britain to be designed

FIG. 10. Paul's film processing laboratory.

for kinematograph work. It comprised a miniature stage, about 28 by 14 feet, raised above the ground level and protected by an iron building with wide sliding doors and a glass roof facing north. At the rear of the stage was a hanging frame to which back-cloths painted in monochrome could be fixed: the frame could be lowered through a slot to facilitate the work of the scene painter. Traps in the stage and a hanging bridge above the stage provided means for working certain effects to which I shall refer later. Eventually a scene-painting room was added behind the studio. A trolley mounted upon rails carried the camera, which could thus be set at any re-

quired distance from the stage, to suit the subject. Sometimes the trolley was run to or from the stage while the picture was being taken, thus affording a gradual enlargement or reduction of the image upon the film. Adjacent to the studio, a laboratory (Fig. 10) was erected, having a capacity for processing up to 8000 feet of film per day. With the valuable aid of Walter Booth and others, hundreds of humorous, dramatic, and trick films were produced in the studio.

A specimen trick film may be briefly described (Fig. 11): Upon the moon-lit battlements of a castle a knight meets his lady-love. The twain are startled by the appearance of a ghost, which, at the approach of the knight, fades away. Meanwhile a witch, complete with

FIG. 11. Scenes from an early trick film (about 1900).

broomstick, appears in the sky and attempts to carry off the lady, but being driven off by the knight, she flies away over the moon. Then a grim ogre, several times the size of the knight appears over the battlements and picks up the lady, who hands him a flaming sword. The scene dissolves to the cave of the witch, where many exciting and fantastic events occur, culminating in the rescue of the lovers and a banquet at the castle. I have summarized this fairy story, which lasted three minutes upon the screen, as an example of what was done at the beginning of this century to pack the maximum of movement into 180 feet of film. It is also an example of the position of the art as regards trick photography. The black magic effects were produced by photographing the ghost against a black velvet

cloth, then superimposing the negative upon that of the main scene, in which is a suitable blank space, and printing the two together.

When dissolving from one scene to the next, the exposure was gradually reduced at the end of the first negative and gradually increased at the beginning of the next. Either a mask, having a wedge-shaped

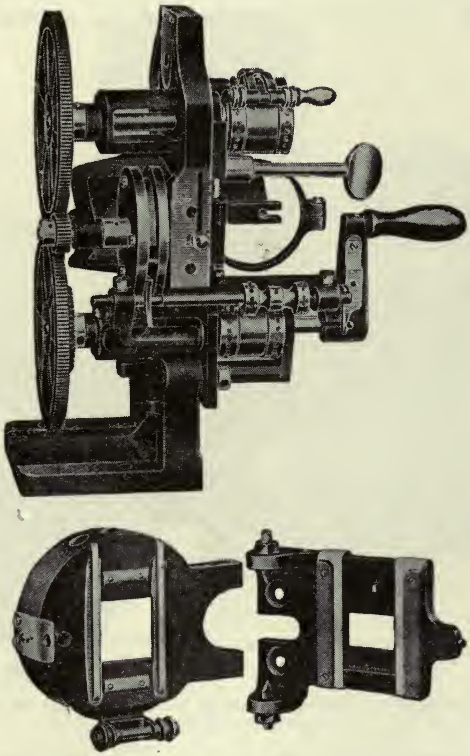


FIG. 12. Three-slot star-wheel intermittent, and gate of projector (1899).

aperture, was moved across the lens by means of a screw feed, or the iris diaphragm was slowly contracted or enlarged during the exposure of an appropriate number of pictures or frames. In the case of a figure taken against a background, the image could be traversed in any direction either by the aid of a mechanically actuated rising front, or by a panoramic movement of the camera itself. By feeding the film upward instead of downward in the camera, the motions could appear as reversed, and a building made to disappear brick by brick.

By repeating in the print a single frame of the negative, a diver could be made to pause in mid-air as long as he desired. By rotating the camera about the axis of the lens, a person could be made to appear to perform the movements of a butterfly, floating about and turning over.

By speeding up the camera, slow-motion pictures were taken, and in this way we were able, under the guidance of Professor Vernon

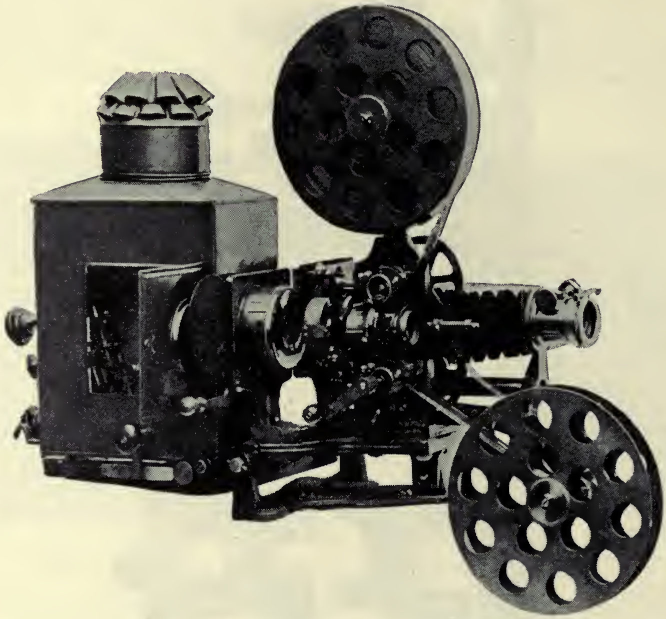


FIG. 13. Complete projector using three-slot star-wheel intermittent (1899).

Boys and Professor Worthington, to obtain pictures of sound-wave "shadows" and falling drops, respectively. A little later Professor Silvanus P. Thompson prepared several series, each consisting of hundreds of diagrams, illustrating lines of force in changing magnetic fields; these we converted into animated pictures by the one-turn-one-picture camera. I had the pleasure of personally presenting copies of these films to Thomas Edison at Orange, N. J., in 1911.

In projectors having the Maltese cross type of intermittent movement, the shutter covering the motion of the film subtended an angle of about 90 degrees, thus involving a noticeable amount of flicker.

To reduce the flicker, and at the same time maintain the illumination, I designed a projector (Fig. 12) in which the Maltese cross, or four-star wheel, was replaced by one having only three slots.[3] Thus the shutter had to cover only about 30 degrees; in other words, the ratio of light to darkness was 11 to 1 instead of 3 to 1. The outfit included

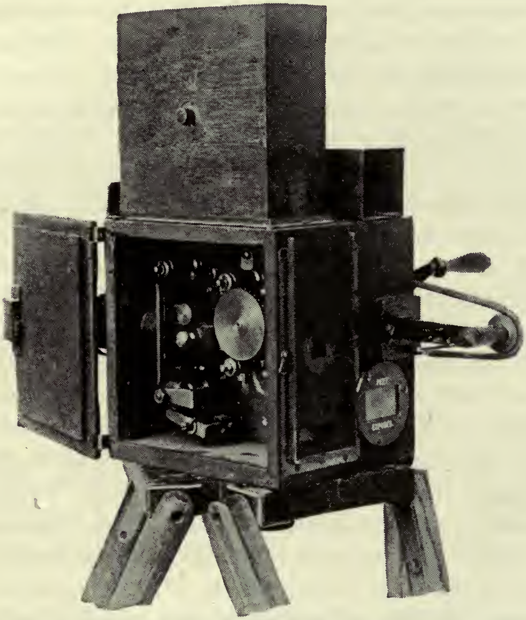


FIG. 14. Camera using three-slot star-wheel intermittent.

a sliding lantern, so that lantern slides as well as films could be shown (Fig. 13). A camera with a similar movement, now in the Science Museum, is shown in Fig. 14; it had detachable dark boxes, full-sized finder, interchangeable lenses with turret mounting, and other features common in present-day practice. This three-slot mechanism did not eventually supersede the four-slot Maltese cross so generally used in modern projectors.

SELLING FILMS

Turning for a moment to the business side of the kinematograph work, showroom premises were taken in High Holborn, and Jack Smith joined the firm as sales manager in 1900. Our maximum out-

put of new film subjects was reached in the period 1900 to 1905. As the staff at Muswell Hill was fully occupied there, taking topical films became the care of Jack Smith and his assistants. Smith also travelled abroad and photographed many popular subjects. In 1900 I produced, through the good offices of the adjutant-general, a whole series depicting life in every branch of the British army.

It soon became the practice of firms, owing to competition, to send out batches of films on approval to many of the exhibitors, in order that the latter might see the latest productions. Many of the less conscientious showmen repeatedly used the samples for a week or more before sending them back as unsuitable. This abuse grew to such an extent as to cause much loss to the makers, and it was eventually abolished by their mutual action. In 1907 there existed in England about ten firms producing pictures, while several exhibitors had cameras and produced occasional topical and dramatic films. Some of them started renting their films, and played off the foreign against the British producer in order to cut prices. To regularize trade conditions Will Barker called the producers together and the Kinematograph Manufacturers' Association was formed. In 1909 this Association, in coöperation with George Eastman, called together at Paris all the producers of films in Europe, and a Convention of conditions of supply was signed by thirty-five firms. Of these, few, if any, exist today. Other activities of the K. M. A. included standardizing film dimensions, training operators and certifying them, and arbitrating in commercial disputes. By 1910 the expense and elaboration necessary for the production of any salable film had become so great that I found the kinematograph side of the business too speculative to be run as a side-line to instrument making. I then closed it down, and destroyed my stock of negatives, numbering many hundreds, thereby becoming free to devote my whole attention to my original business, now a part of that of the Cambridge Instrument Company.

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[2] PAUL, R. W.: Brit. Pat. No. 4686, March 2, 1896; covering segment shutter, marginal pressure pads, and spring compensation for sprocket variations.

[3] PAUL, R. W.: Brit. Pat. No. 487, 1899.

USE OF MOTION PICTURES IN AN ACCURATE SYSTEM FOR TIMING AND JUDGING HORSE-RACES*

H. I. DAY**

Summary.—*An accurate system for timing and judging horse-races installed at Santa Anita Park, Calif., consists of photoelectric cells placed around the track at appropriate positions; a visual electric timing board placed in the infield; two electrically driven cameras associated with electrically driven clocks mounted in a booth above the grandstand exactly at the finish line; and rapid film processing and printing equipment connected to the cameras in a darkroom immediately behind them.*

The horses at the starting position interrupt the light-beam focused upon the photoelectric cell, transmitting an impulse to a central control cabinet mounted in the camera booth, and thence to the electric clocks associated with the cameras and to the rotary selector switches operating the electric timer in the infield. The time of each quarter-mile interval of the race is recorded visually on the electric timer.

Two special 16-mm. cameras are mounted exactly at the finish line, and are equipped with a double-lens train: one to photograph the horses crossing the line; the other to record, on the same frame, the reading of the clock associated with the camera. The cameras are driven by synchronous motors at speeds of 62 to 101 double frames per second. The electric clocks are crystal-controlled at 200 cps. The clocks are started by the impulse from the first photoelectric cell in the race, and stopped manually after the cameras are stopped. The cameras are operated manually to photograph the order and the time of the finish.

It has been recognized for a great many years that the methods of judging and timing horse-races have been subject to human errors. To minimize these errors three judges have usually been employed at the finish. Notwithstanding this precaution, errors have frequently occurred in the timing and judging, and there have been no available means for eliminating them. By utilizing the recent advances in the electrical and motion picture industries, there has been developed within the past few years an accurate and dependable mechanical system for timing and judging. This system has proved entirely accurate and satisfactory, and has been received with a great deal of enthusiasm by the horse-racing public.

"Who won?" is the question asked at the end of every race, and

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* Presented at the Spring, 1936, Meeting at Chicago, Ill.

** New York, N. Y.

its answer is the most important message that can be conveyed to the racing public. But, who did win? The winner was selected by three well trained, capable, but nonetheless human, judges who make every effort to detect the changes that occur so quickly that often the human eye can not see or the human brain remember them.

Due to experience, training, and a better position for viewing the races, the judges are more generally right in their decisions than is the public except when the public can sit opposite the finish line. Correctness of decision is of little value if the public thinks the judges are wrong. The public must be pleased and satisfied. In other words, the public must see the finish exactly as the judges saw it. By presenting to the public a photograph of the finish, used by the judges in determining the winner, the judges are relieved of embarrassment and the public is taken into their confidence, and the layman will concur with the judges' decision.

The average speed of a running horse is approximately 55 feet a second; the length of a running horse is approximately 11 feet; hence, a horse moves five times his length in one second. Considering the shorter values of distance of importance in racing, namely, *nose* (3 inches), *head* (1 foot), *one-half length* (5 feet), *etc.*, the interval of time necessary to bring about these changes between two running horses is much less than that required to bring about a change of one horse length. As the "head" is regarded approximately as one foot in length, horses may change their positions by a "head" in $^1/_{11}$th of the time required by a change of one "length"; in other words, $^1/_{55}$th of a second. Offhand, some would imagine that the governing factor in viewing a race finish would be the persistence of human vision, which is from $^1/_{30}$th to $^1/_{50}$th of a second. But to reach this conclusion would be judging from too few particulars.

During the 1934 racing season the judges and stewards at Santa Anita were fully coöperative and kind enough to advise the writer every day of their confidential opinions as to the order of finish and the distances between the horses involved. By reconstructing the races on a miniature track with miniature horses we were able to determine that the judges rarely saw the horses on the finish line. We also determined the positions of the horses with respect to the finish line at the last instant each judge had a definite visual picture of them. For the moment, suffice it to say that, when the horses at the finish are a few feet apart, the human eye rarely sees more than

four distinct images a second; and, if the horses are only a few inches or a few feet from the finish line, the oblique viewing (or parallax), plus differences in magnification as relates to eye-image size, and differences in angular velocity with consequent differences in apparent speed as a function of the distance from the judges' eyes, may cause the mind to register false impressions of the relative positions and speeds of the horses. These data will be more fully discussed at some later date, as this paper deals only with the mechanisms used for timing and judging the finish. If four distinct images per second can be seen, and the horse moves 55 feet in one second, it is easy to see that a horse may move approximately 14 feet between two consecutive distinct views of the horses. Moreover, the instant of vision of one judge may not be synchronous with that of another, and the last clear view of the horses may occur anywhere from a few inches to 12 or 14 feet from the finish line.

The means for detecting these small changes in time and position are provided by viewing a photograph taken simultaneously of the finish and of an accurate electric clock by a high-speed motion picture camera located at the finish line.

The element of time is a very important factor in racing. The horses are weighted in accordance with the times of their previous performances. The purpose is to put on the horse a weight that would make him equal to all other contestants. Theoretically, all races should be "dead heats." Using the weight as a handicap, we must know, with some degree of accuracy, how well the horse responds to the weight he is required to carry in the race. This requires an accurate method of timing. If the timing method is inaccurate, the handicapping is improperly determined, and the horses do not run in accordance with their real ability.

It may be well to discuss, briefly, the method and errors in manual timing. The use of accurate timing in horse-racing is peculiar to the United States and Canada. In most foreign countries, the time of the race is not considered essential. In American racing, we have chosen to set up the time of a race as the standard of performance. The practice in horse-racing is to record the time, within one-fifth of a second, of each quarter-mile interval, and the complete time as well. The complete time is usually posted for public viewing. The interval times have not heretofore been shown to the public, although they are a part of the race record. The timers are usually stationed at the finish line. As the horses start, a man stationed at the position

of start drops a red flag, and the timers start their stop-watches. This introduces the first error. The flag may be slow or fast, and the timers may or may not start their watches exactly as the flag drops. Errors of $\pm ^3/_5$ second may occur. As the horses go around the track, the timers record the time when they think the leading horse passes the quarter-mile posts. The watches are not stopped at the intervals. When the timers think the horses have passed the interval, they glance at their watches and attempt to read the time to one-fifth of a second. It is obvious that unless the timers are stationed at the interval posts, and stop their watches, they can not record the exact time. When the horses are coming toward or going away from the timers, or are going around a turn, the angle of vision is such that the timers can not determine exactly when the leading horse passes the interval post. At the finish, due to variability in the rate of reaction, some timers anticipate and others are slow, thus introducing over-all errors. In addition to these human errors, there are the errors in the watches that are used. Some watches run fast, others slow, due to mechanical defects and irregular windings. As a general result, the times recorded by different timers do not agree within one-fifth of a second, and it is highly desirable to utilize some accurate means for determining this time.

Recognizing these conditions, Dr. Charles H. Strub and Mr. Gwynn Wilson, officials of the Los Angeles Turf Club, sought to have made available at their Santa Anita Race Track at Arcadia, Calif., a system that would correct, so far as possible, the errors and difficulties inherent in the old methods of timing and judging. These gentlemen were quite familiar with the electrical timing and judging equipment used at the Games of the Tenth Olympiad, at Los Angeles in 1932. The system described below is the outcome of their inquiry, and embodies some of the basic principles of the equipment used in the Olympic Games. It is designed primarily for the problems of horse-racing. The reliability of the equipment, the simplicity of operation, and the ability to deliver the finished photographs quickly enough to assist in judging the race, are fundamental requirements of such judging and timing equipment. Stated in another way, the problem is to make a clear photograph of the finish, and to determine accurately the time and position of every horse in every race every day.

With the coöperation of the Eastman Kodak Company and the Kodak Research Laboratory, the elements of error previously in-

volved in timing and judging races have been entirely eliminated by means of the precision timing and judging system mentioned above. The equipment consists of photoelectric cells and associated exciter lamps placed at intervals around the track, and all connected, through a central control cabinet mounted in the camera booth, to the visual timer and electric clocks attached to the cameras. The camera booth is on top of the grandstand at the finish line. Two high-speed 16-mm. Eastman cameras are mounted in the camera booth, one above the other, and lined up with surveying instruments exactly at the finish line. Each camera, integral with an electric clock, has a double lens train, and is directly connected to rapid

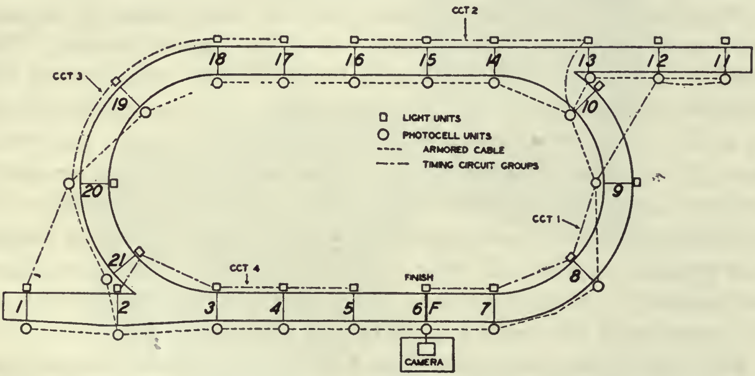

FIG. 1. Positions of photoelectric cells, exciting lamps, and timing circuits; Los Angeles Turf Club, Arcadia, Calif.

film processing equipment. The electric visual timer is mounted in the infield adjacent to the totalizator.

The cameras and the rapid film processing machine used in this system are special products of the Eastman Kodak Company Development Department. Credit must be given to Mr. F. E. Tuttle, who assisted the author in combining the various elements into a unified working system.

Fig. 1 shows the positions of the photoelectric cells around the track. There are 21 positions, which, when properly combined as to sequence, will time any length of race as usually run at this track. They are electrically connected in four distinct groups, such that in any race, regardless of length, only one photoelectric cell in each group is in operating condition at a time. The photoelectric cell at

the finish line is used in all races, and also for the start of the mile or two-mile races.

The operation of the units is as follows: All the exciting lamps are lighted all the time. They are 6-volt automobile lamps fed by a 110-volt a-c. circuit, which is stepped down to 6 volts by a transformer at each lamp. If the race is a six-furlong three-quarter mile race, the operator at the control cabinet connects the series of photoelectric cells at positions *13*, *17*, *21*, and *6*, and the start key in group *2*, so that impulses can be received from these positions at the control cabinet. These positions represent quarter-mile intervals from the start at position *13*. No other photoelectric cells on the track can send an impulse into the control cabinet. The horses leaving the starting gate and passing position *13* at the start cause an impulse to be sent from this photoelectric cell to the camera booth. This impulse starts the electric clocks attached to the cameras and the selectors of the visual timer. Also, position *17* is automatically set up as the next active photoelectric cell. When the horses pass position *17*, the first interval of time (that is, for one quarter-mile), appears upon the electric visual timer. In passing position *17*, photoelectric cell *21* automatically becomes active. As the horses pass position *21*, the half-mile time appears upon the visual timer, and position *6* at the finish is automatically cut into the circuit. As the horses pass the finish line, the finish time appears.

When the horses are approximately two lengths from the finish line the cameras in the booth are started manually. The film is fed directly into the darkroom, developed, fixed, and then passed directly to the enlarger. If the race is close, the judges call the darkroom and ask for a print or prints showing the positions of the horses at the finish line. If the finish is sufficiently open to be judged without a photograph, one print is made of the winning horse at the finish line. The time required to complete the first print is approximately $2^1/_4$ minutes from the time the first horse crosses the finish line.

The photoelectric cells are mounted upon posts about $4^1/_2$ feet from the ground; the top of each post has a steel plate containing two guides or dowel pins for centering the unit more or less accurately upon the base-plate. The exciter lamps are similarly mounted, one across the track from each photoelectric cell. A 16-pair, 19-gauge cable connects the photoelectric cells to the control cabinet. A 110-volt a-c. circuit connects all the exciter lamps around the track.

Fig. 2 is a view of the lamp and photoelectric cell housing. Ex-

ternally, the two units are identical. The lamp housing contains an infrared filter, which prevents visible light from appearing upon the track and causing the horses to become excited or frightened. The lamp in the lamp house is capable of being adjusted in three directions from the correct focus position. As previously stated, the lamp is a 6-volt automobile headlamp. The voltmeter at the back of the housing indicates the voltage on the lamp at all times. The photoelectric cell housing contains a *3-A* Western Electric caesium photoelectric cell. This is connected to a one-tube a-c. operated amplifier.

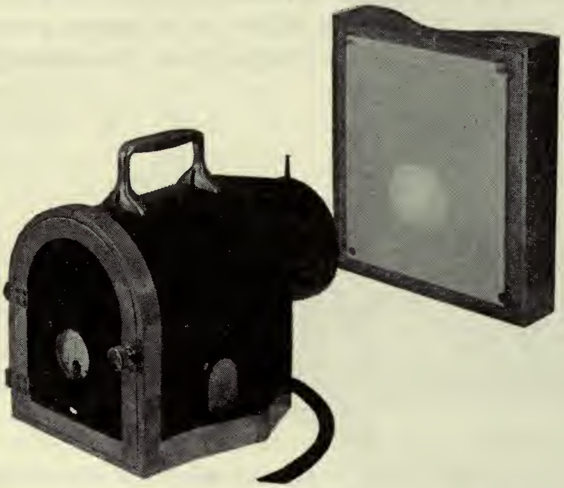

FIG. 2. External view of photoelectric cell and lamp housings.

The plate current of the amplifier is indicated by a meter at the rear of the housing, similar in appearance to the meter on the lamp house. In front of the photoelectric cell is placed a diaphragm having an opening of the proper size, upon which aperture the light from the lamp across the track is focused directly, thus preventing stray light interference. A $4^1/_2$-inch lens is used in the lamp house, and a 3-inch lens in the photoelectric cell. These lenses are properly placed so as to bring the light from the exciting lamp to a sharp focus upon the aperture previously mentioned. Records are kept of the values of current in the photoelectric cell and the lamp, and each morning prior to the start of the races, all these units are inspected, dirt and condensed moisture are removed from the lenses, the connections are

checked and various other routine operations performed. By watching the voltmeter in the lamp house it is possible to anticipate the end of a lamp's life and thus to replace the lamp before service is interrupted. By daily checking the photoelectric cell and its amplifier, similar protective measures can be established. Fig. 3 shows the inside of the lamp and photoelectric cell housings.

Fig. 4 shows the control cabinet which is mounted in the camera booth. At the lower position are four keys, representing the four photoelectric cell groups previously mentioned. The keys in the upper section are connected individually to the photoelectric cells around the track. The control cabinet is the master control unit of the entire timing and photographing system, since the impulse from

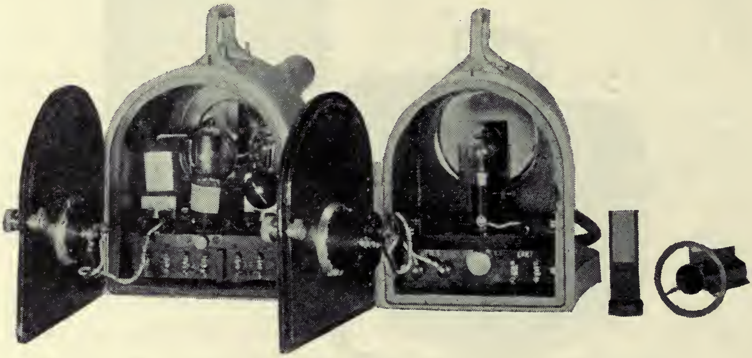

FIG. 3. Inside view of lamp and photoelectric cell housing.

the starting photoelectric cell is received in this cabinet and is transmitted to the electric clocks attached to the cameras, as well as to the visual timer. By setting the proper keys on the cabinet, the sequence of photoelectric cells for timing races of any length in quarter-mile intervals is established. After the race has been completed, a reset key removes the visual time and restores the rotary selectors in the visual timer to zero.

There will also be noted on the control cabinet a replica of the race-track. This replica contains four red lamps, mounted on the outside, which indicate the quarter-mile intervals and show that, as the race is being run, the proper photoelectric cells are automatically put into operation. Each of these lamps represents the group of photoelectric cells mentioned above. The white lights represent the first cell to be used in any given series, and hence the first at the

start of the race. The red light may represent any photoelectric cell in the group, but while a given race is being run it is connected to only one photoelectric cell in that group. As the race progresses, the red light flashes on and off as the passing horses make the corresponding photoelectric cell operative or inoperative.

As the race is being run, the time appears upon the visual electric timing board, as shown in Fig. 5. The time of each quarter appears as the horses pass the exciter beam representing the end of that quarter-mile, and as soon as the horses pass the finish line, the final time appears immediately. At Santa Anita the visual timing system contains five banks of rotating selectors, for timing five intervals; that is, up to and including $1^1/_4$ miles in quarter-mile intervals. Two banks read up to $59^4/_5$ seconds, and have three selectors each. In three banks, there are four selectors, giving the minutes, ten seconds and seconds, and fifth seconds. The timing panels are cabled to the indicator units used by the totalizator, so that the visual time appears in the same kind of digits.

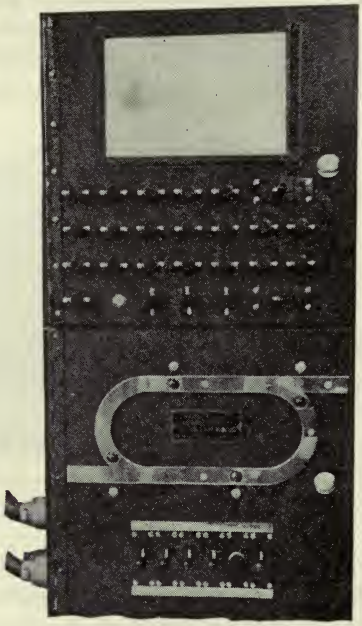

FIG. 4. Front view of control cabinet.

The timing equipment is fully automatic. After a race has started, no one in any way can change or interfere with the times shown, as the equipment is directly tied in with the photoelectric cells. As the first exciter lamp beam is interrupted, all the selectors necessary to time the race begin to operate. In a $^3/_4$-mile race, three banks of selectors start, the other two having been cut out of the circuit. The driving system for the selectors is a 50-cycle a-c. synchronous motor, which drives a commutator supplying the pulses for stepping the selector switches at the proper intervals. As the horses pass the first quarter-mile post, the first bank of selectors stops operating, and a relay is pulled up causing an electrical contact to be established between

the selectors and the proper digit combination in the indicator unit. The time appears automatically. After the second quarter-mile interval, a similar operation takes place, and so on for the duration of the race. The selectors are adjusted to record the time in the same manner as a stop-watch; that is, the selector does not move until the $^1/_5$-second interval has passed. The time shown by the visual timer, therefore, corresponds to that usually given for racing, although it is not accurate to less than $^1/_5$th of a second.

When the first impulse is received from the photoelectric cell at the starting position, the control cabinet transmits the impulse to the electric clocks mounted underneath the cameras as well as to the

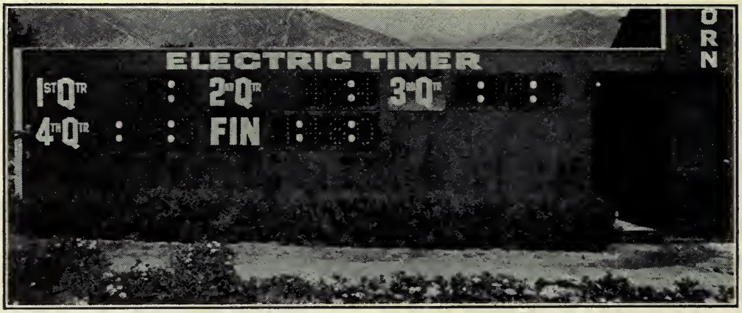

FIG. 5. External view of visual timer.

visual timer. The electric clocks used with the cameras have been described in detail in other publications.[1] However, a review of the design and operation of the clock may be of interest. It consists of three concentric dials, the inner or upper of which, as shown on the finish photograph, records hundredths of a second. The middle dial records seconds, and the lower records minutes. To correct for a constant delay in the mechanical clutch, the hundredths dial is set forward 0.006 second, so that when set to zero, the dial actually reads 0.006. The clock is driven by a synchronous motor rotating at ten revolutions per second, which is, in turn, controlled by a 200-cycle crystal- and temperature-controlled tuning-fork generator. The motor shaft is connected to the clock mechanism by means of a magnetic clutch, and is so arranged that the clock dials are stationary when normally set to zero. In the top of the mounting plate on the clock are two windows, each $^3/_8$ inch wide and $^3/_4$ inch long, dis-

posed 90 degrees from each other in the clock mounting face. One of the apertures is directly over the zero position of the dials. The optical system of the camera which conveys the clock image to the film, is placed immediately above this aperture. The viewing aperture is 90 degrees from this photographing aperture. The dials are so marked that when set at zero in the photographing aperture, the viewing aperture indicates that they are in the correct position. The clock dials in the photographing aperture are illuminated by small automobile headlight bulbs.

The accuracy of the clocks depends naturally upon the accuracy

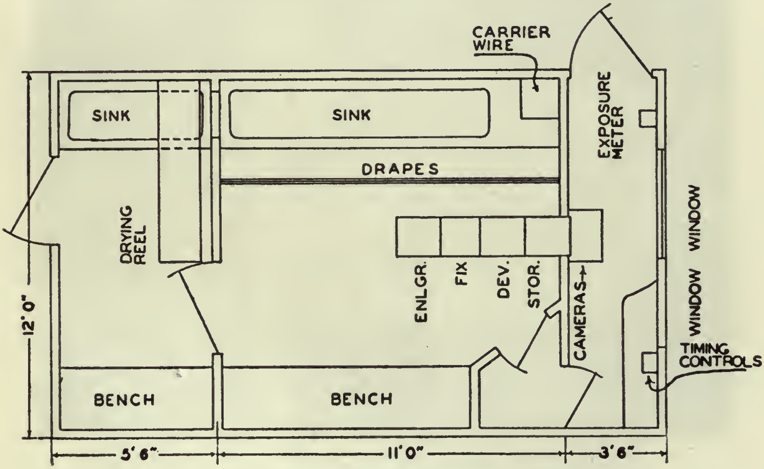

FIG. 6. Floor plan of camera booth.

of the 200-cycle frequency supplied to the synchronous motor by the crystal-controlled tuning-fork generator. This generator operates on a 110-volt a-c. line, the output passing through a suitable amplifier to actuate the clock. The frequency output of the amplifier, measured in decibels, is 97.5 at 200 cps.

The constancy of this generator has been determined, and the maximum error in rate is not over 0.01 second in five minutes. The clocks are started by the impulse from the first photoelectric cell in the series, and run continuously until stopped manually after the camera has been operated at the finish line. The clocks are easily reset to zero by rotating the reset dial which is the portion of the mounting plate containing the two apertures previously discussed.

The photographic equipment and electrical control cabinet are housed in a 12 × 20-ft. booth upon the top of the press box above the grandstand. Fig. 6 is a floor plan of the construction. The track is 85 feet wide, and the lateral distance from the outside of the track to a vertical line through the cameras is approximately 110 feet. The lower camera is placed approximately 77 feet above the track, and the upper camera approximately $78^1/_2$ feet. The maximum distance from the lens of the upper camera to the inside rail of the track is 210 feet. Since the race usually finishes on the inside half of the track,

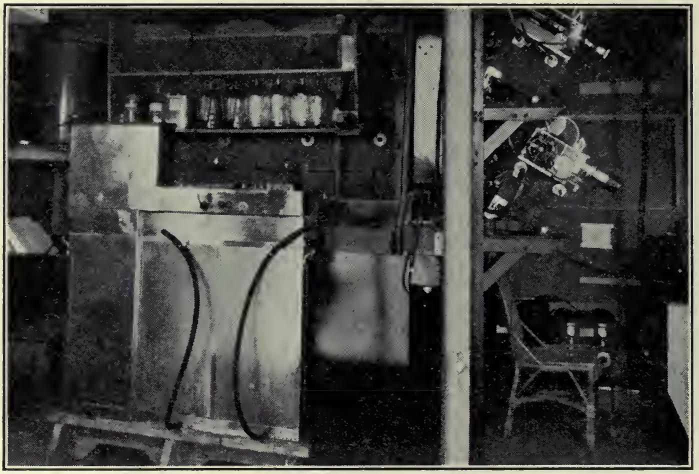

FIG. 7. Arrangement of photographic equipment in camera booth.

it is assumed that the minimum distance from the camera to the nearest horse is 170 feet. It will be noted in Fig. 6 that the cameras are placed against the back wall of the front room of the camera house. The cameras are tilted down so that the lenses see the track at an angle of approximately 25 degrees below the horizontal.

The electrical control equipment also is housed in this room. Immediately behind the camera room proper is the first darkroom, housing the film processing and enlarging machine and having the usual sink and work-bench. The rear room of the house can be made dark, and is used as a loading room, for mixing chemicals, and for drying the film. The chemicals and raw film are stored in a room below the camera booth and back of the press box. Daily supplies

are brought up as needed. At one corner of the middle room, as shown in Fig. 6, is the end of the wire down which a carrier slides, when released by the operator, bearing the pictures to the judges' stand. The camera house is equipped with the usual safelights, water supply, and electrical connections. Adequate ventilation is provided. The design of the house seems to be satisfactory in that all the various phases of the work can be carried on simultaneously without con-

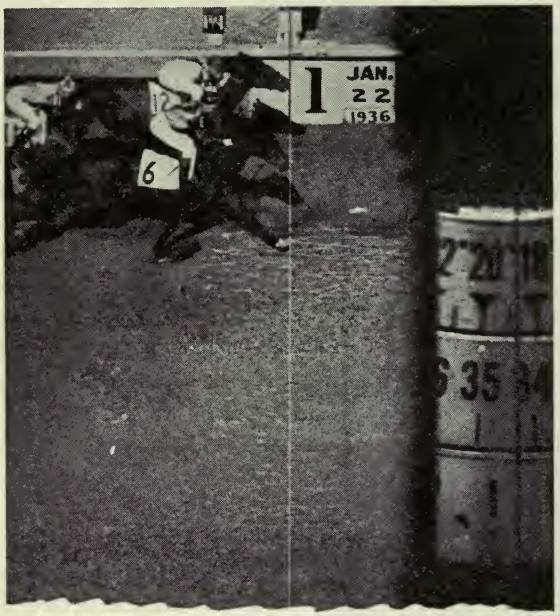

FIG. 8. Print of finish of race.

fusion or interruption. The windows shown in the camera room are kept closed in bad weather to prevent damage by rain and wind. Just before the race, the large window in front of the cameras is opened by swinging it outward laterally, thus providing protection for the camera lenses against the rain. During operations all doors of the house are closed and, if necessary, locked. No one except the operating crew is allowed inside the camera house while the finish of the race is being photographed and the film developed. Communication is provided by private telephones to the field maintenance man who is usually stationed at the start of the race, and also to the judges' stand and the visual timer in the infield.

Fig. 7 shows an arrangement of the photographic equipment in the camera booth. The wall between the camera room and the dark-room has been cut away. It will be noted that the two cameras are mounted one above the other upon a fixed frame. They are on a surveyed extension of the finish line, and are rigidly mounted, and not moved during the racing season. Immediately to the rear of the cameras is the dry-film storage-box, followed by the rapid developing chamber, then the fixing chamber and, last, the enlarging unit. The film passes directly from the cameras into the storage-box and then through the other steps in the operation in the order named.

The cameras used for the work are special 16-mm. Eastman cameras. Due to the fact that the field that is photographed is a narrow cross-section of the track, 85 feet wide and very narrow laterally, as the camera sees it, it has been necessary to change the pull-down mechanism in the cameras from a one-frame to a two-frame pull-down. This means that longitudinally on the film we are able to photograph the cross-section of the track with a sufficient lateral dimension to take in at least $1^1/_2$ lengths before the finish line and at least $^1/_2$ horse length after the finish line. The final frame is 0.589 inch (14.96 mm.) long. Since we are making a double exposure, namely, of the horses and of the clock, it has been necessary to divide the frame longitudinally so that the width of the picture frame is approximately 0.31 inch (7.88 mm.) wide, the remainder of the width being taken by the clock image at the right-hand edge.

The cameras are driven by induction motors operating on the 110-volt a-c. line and connected to the cameras by means of clutch arrangements. A "start" button starts the cameras, and film is fed past the aperture in the usual manner. The cameras are started when the leading horse is within a certain distance of the finish line. The distance is not rigidly fixed, but depends upon the procedure of the particular camera operator. A special negative film produced by the Eastman Kodak Company is used. It is not the usual reversal type 16-mm. film. At Santa Anita, 4-inch $f/2.7$ lenses are used exclusively.

Since photographs must be taken of every race regardless of the time of day, it is necessary to provide artificial illumination, consisting of two 10-kw. studio type spot lamps placed in a small house above the camera booth. The lamps are focused upon a given area at the finish line, and are so mounted and protected as not to frighten the horses. The amount of light thus provided is satisfactory, although naturally more light could be used if it were readily available.

The construction of the camera and the developing machine have been described in a paper by Tuttle and Green.[2] After the required number of prints of the finishing frames have been made, the film is removed from the machine and given complete fixing, and washed and dried in the usual manner. The film from each day's operation is held by the Turf Club officials.

The size of the print is $5^3/_8 \times 8^5/_8$ inches. The first print made is sent to the judges immediately, in the special metal carrier sliding down the steel wire. Subsequently, other prints are made and posted at various positions about the race-track for viewing by the public. One print is made of the winning horse in every race, and this print, in addition to all other prints of contested positions, is given to the Turf Club for their records. Making these prints is a rather rapid procedure, and in some cases as many as 40 prints have been made in 30 minutes' time. The first print must be delivered to the judges in less than three minutes after the finish of the race.

Fig. 8 is a reproduction of a print produced by this equipment. In this picture the noses of the two horses are exactly upon the white line extending across the track. This white line is a $^1/_4$-inch steel cable stretched across the track some 15 feet above the finish line. The number of the race is represented by the large figure *1*, and the date is as shown, January 22, 1936. This is a dead heat for the second-place horses, the first horse having moved

DEC. 25

First race—Jubilee Jim nose over Lady Florise, and paid \$9.60, \$5.60 and \$4.00.

Third race—Bartlett nose over Vermont Rose, and paid \$5.80 to win.

DEC. 26

Third race—Budding Star nose over Jock's Image, and paid \$16.40, \$8.80 and \$6.60.

Fifth race—Rodney Pan a nose over Skipton, and paid \$9.20 to win.

Seventh race—Marsala nose over Fair Mole, and paid \$12.20, \$5.00 and \$3.80.

DEC. 27

Second race—Leciarious nose over Speed Girl, and paid \$6.40 to win.

DEC. 28

Second race—Morpheus nose over Afridi, and paid \$99.60, \$42.40 and \$19.20.

Fifth race—Open Range nose over Postscript, and paid \$10.60 to win.

Sixth race—Soon Over nose over Sound Advice, and paid \$10.40 to win.

Seventh race—Galiaclay nose over Dark Winter, and paid \$6.80 to win.

Eighth race—Toro Mak nose over Interpreter, and paid \$29.60, \$12.40 and \$7.40.

DEC. 30

Sixth race—South Gallant nose over High Image, to pay \$6.40. High Image would have paid a good price if he had kept his nose in front, since he paid \$11.40 to place.

Seventh race—Lady Roma nose over Georgia Miss, and paid \$6.40 to win.

DEC. 31

First race—Bay Buddy nose over Stolen Color, and paid \$115.60, \$59.20 and \$21.80.

Second race—Blackboard nose over Shady Girl, and paid \$7.00 to win.

Third race—Dokas nose over Mumsie, and paid \$6.80 to win.

JAN. 1

First race—Star Brook nose over Rosemaid, and paid \$21.00, \$12.20 and \$7.20.

Third race—San Ramon nose over Davidor, and paid \$32.20, \$9.40 and \$5.40.

JAN. 2

Fifth race—Draft Sergeant nose over Sundad, and paid \$11.80 to win.

Sixth race—Seguro nose over American Emblem and paid \$10.40 to win.

JAN. 3

First race—Bonicon nose over Mignon, and paid \$11 to win.

Third race—Shady Girl nose over Dark Mist, and paid \$15.40 to win.

(P. S.—These figures don't include the neck and head finishes, and there were plenty of these, too.)

FIG. 9. Record of nose finishes during first 56 races of 1935–36 Winter Season at Santa Anita, Calif. (from a newspaper column by Neil McDonald).

out of the picture. The time of the two horses is shown in the clock as 0:34.19. The race was $^3/_8$ mile long. The time of the winning horse was 0:33.92, and would be taken 27 frames before this frame. It will be noted in the photograph that the number upon the saddle cloth of the inside horse is rather indistinct. This is due to the fact that this number is red on a white background. The number *6* on the outside horse is black on a white background, which photographs very easily. The distance between the two horses, laterally, is indicated by the fact that another horse can be seen coming up between them.

It is in finishes such as these that this equipment is invaluable. During the year 1935, a total of twenty dead heats in American racing were reported. During the past season at Santa Anita, covering 464 races, five dead heats were determined by the use of this camera equipment, two for first, two for second, and one for third place. This is said to be the first time in the history of racing that a dead heat for third place has been declared. In the first 56 races of the 1935 Santa Anita season, 22 nose finishes, involving winners, were decided with the aid of the camera (Fig. 9). Of the 464 races, 141 finishes required the photographs for judging. In conclusion, it can be stated that the equipment operated satisfactorily; a picture of every race was taken during the period of 58 racing days of the 1935–1936 winter meeting and during the 1934–1935 winter meeting after the apparatus was officially put into use. No difficulties were encountered that would in any way invalidate the accuracy of this system of judging and timing races. The system has been received enthusiastically by those interested in horse-racing, and it is felt by these people that the system marks a distinct advance in the methods of timing and judging races.

REFERENCES

[1] DAY, H. I.: "Precision Timing of Athletic and Other Sporting Events," *Electrical Engineering*, **52** (June, 1933), No. 6, p. 386.

[2] TUTTLE, F. E., AND GREEN, C. H.: "Photographic Race-Timing Equipment," *J. Soc. Mot. Eng.*, **XXVII** (Nov., 1936), No. 5, p. 529.

PHOTOGRAPHIC RACE-TIMING EQUIPMENT*

F. E. TUTTLE AND C. H. GREEN**

Summary.—*As a result of the necessity for greater accuracy in rendering decisions of racing events, without appreciable delay, equipment was developed to permit viewing paper enlargements made from 16-mm. motion picture negatives of the finishes within three minutes. The general requirements of the early rapid processing machine are given together with a description and schematic sketch of the machine, and the early cameras and their requirements are also mentioned.*

As a result of experience gained in the field with this equipment, certain changes were desired. The design of the new camera is considered in detail, and illustrations of the camera and results accomplished with it are shown. The new processing machine and its enlarging head are described and illustrated.

The problem of determining the winner of a race is a very real one, so real that it warrants the use of elaborate electrical timing equipment, high-speed cameras, and a means for rapidly developing the negatives and supplying paper enlargements. The systems employed for timing races in 1932 have been described by Fetter.[1] Since 1932 considerable advance has been effected by making the equipment more practicable, and a recent installation of race-timing equipment, with particular reference to the electrical apparatus used, has been described by Day.[2]

It is the purpose of this paper to describe the photographic equipment used in conjunction with this electrical equipment, and to show how the camera, developing machine, and enlarger became the elaborate apparatuses they now are. We began by trying to use standard equipment. Troubles during use, one by one, forced us to change a part here and add a feature there until by trial and error we arrived at the present unit.

Sixteen-millimeter film was selected at the start for use in the camera because it is somewhat cheaper and more easily handled than 35-mm. film. Sixteen-millimeter film is still used, but the 16-mm. dimension is about the only characteristic that remains to prove that

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* Presented at the Spring, 1936, Meeting at Chicago, Ill.

** Eastman Kodak Company, Rochester, N. Y.

the present machine is related to its very conservative predecessor. The film itself, which started out as standard negative material, now has a special thin coating of fine-grain, high-speed emulsion, and is made to withstand high-temperature, high-concentration development.

The standard 16-mm. frame size was originally used for the pictures. Unfortunately, however, horse-race tracks are 85 feet wide, and to be assured of having all the horses appear in the picture,

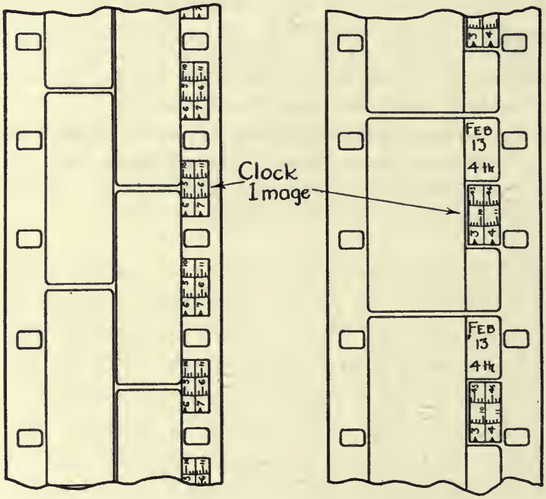

FIG. 1. FIG. 2.

FIG. 1. The staggered-picture arrangement used at first to cover a long narrow field.
FIG 2. The standard two-frame-high aperture now used.

the entire 85-ft. width has to be covered by the camera, which is so positioned as to look down upon and across the track. We found that upon the film we had 0.030-inch horses with 0.003-inch numbers and 0.001-inch noses stretching out in the effort to win $100,000 purses. Something had to be done to increase the picture size. We recognized that the shape of the field that we had to cover was quite unusual. In a camera in which the film ran vertically it was apparent that a long frame was needed to cover the width of the track, but that a very narrow one would do to cover something like a horse's length along the track. Our first attempt to make

long, narrow pictures seemed very good, inasmuch as we were able to take pictures two frames high, using a single-frame pull-down camera, and no more film was needed for a given number of two-frame-high pictures than for the same number of single-frame-high pictures. This was accomplished by staggering the pictures upon the film, as shown in Fig. 1. After a single-frame pull-down, the right-hand half of the aperture of a two-frame gate was opened by a shutter and exposed. After exposure the shutter closed, and the single-frame pull-down advanced the film a frame. Another shutter would then open, uncovering the left-hand side of the two-frame gate. A specially designed, field-dividing beam-splitter placed in front of the lens gave a double image of the finish line, one image for each half-frame. This innovation was too smart. The enlarger crew experienced considerable difficulty in locating the paper frame for enlarging so as to show the finish, and the public could not understand the relation of the pictures to each other or to the clock times shown upon the side of the film. So we had to abandon the staggered-frame arrangement, and went to the present design which takes a picture a full frame wide and two frames high, as shown in Fig. 2. The present two-frame size is almost as large on 16-mm. film as the usable single-frame area on 35-mm. film.

We have tried placing the clock image in almost every section of the picture, and are well pleased with the present arrangement, shown in Fig. 2. The upper right-hand corner is used for a chart showing the date and the number of the race. The lower right-hand corner is available for listing the horses in the race, the jockeys, the order of finish, or other pertinent data.

This clock position, however, did not simplify the camera construction. We very soon found that we needed different shutter openings for the clock picture and the main picture. To produce distinct images, the exposure time must be short enough, of course, to stop the motion; and a shutter opening stopped down enough to give clear pictures of the horses was not small enough to produce sharp pictures of the clock. We saw no satisfactory way of using different shutter openings with the clock located at the middle of the picture, where we wanted it. However, a satisfactory solution was found by providing a specially made camera shutter having one opening to expose the clock and horse pictures, and another entirely independent opening to control the length of time during the exposure period over which the clock dial was illuminated. A diagram of this

shutter arrangement is shown in Fig. 3. Clock exposures are made by means of a stroboscopic light, and clock exposure times are controlled entirely by the stroboscopic opening in the shutter.

We started out in the hope that we could operate the camera at a speed of not more than sixty pictures a second; although we realized that at that taking speed we could not hope to show the finish picture with the winning horse's nose always exactly at the finish line,

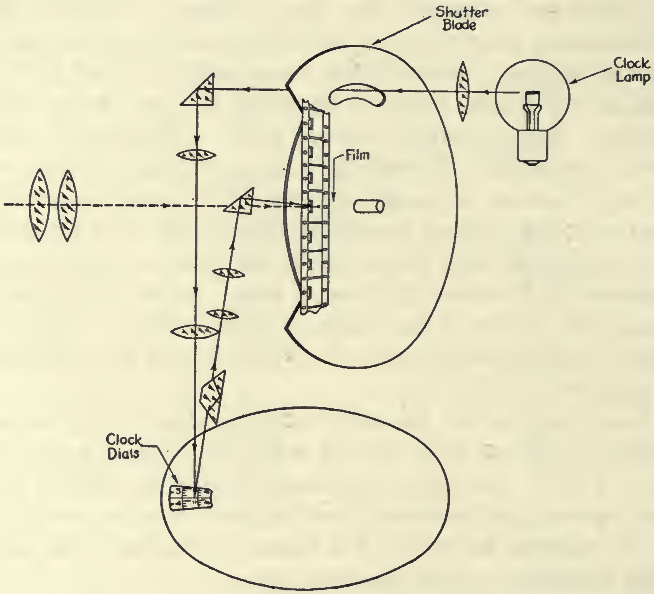

FIG. 3. Schematic arrangement of clock illumination, main picture, and clock picture optical systems.

or with the clock picture always showing the exact time that it took the winning horse to run the race. We planned to show two consecutive pictures to the judges and to the public: one showing the relative positions of the horses not more than $^1/_{60}$th of a second before they reached the finish line; and the other showing their positions not more than $^1/_{60}$th of a second after they crossed the finish line. From these pictures and from the clock pictures associated with them, we felt that the judges could determine the winner and compute the time by interpolation. Such procedure is not at all uncommon in the physics laboratory. We very soon found out, however, that judges

were not physicists, and that the race fans, in spite of their glib talk about odds and probabilities, were not mathematicians. We had to show pictures of the horses with their noses almost touching the line. A horse travels about 55 feet a second. A camera operating at a speed of little more than 100 frames a second would show the finish with a maximal displacement of ±3 inches. This displacement was the largest that anyone associated with racing could be induced to accept, so we increased our camera speed. The present cameras have a top speed of about 165 pictures a second.

The increased number of pictures per second and the increase in height of individual pictures meant that we had the problem of handling more film for developing than we had anticipated. In

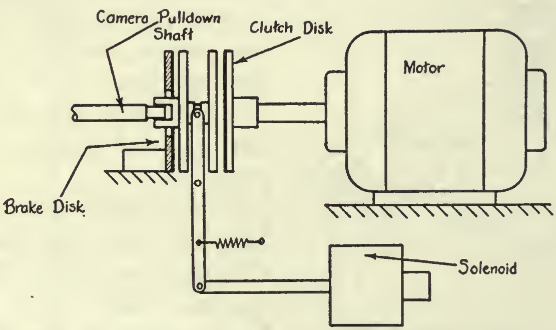

FIG. 4. Clutch and motor assembly for camera.

order to reduce this length to its minimum, we decided to design a special motor drive for the camera—a drive that would, by means of an electric solenoid clutch, start the camera instantly at full speed, and would have a brake so arranged that when the solenoid current was cut off, the camera would stop almost instantly. Fig. 4 shows a picture of this motor and clutch assembly.

Instant starting and instant stopping meant trouble with the supply reel. A 200-ft. reel does not wish to be started or stopped quickly. When the camera was stopped, the supply reel would keep running so that a lot of loose film would accumulate above the supply sprocket. When the camera was started again the loose film would have to be taken up. As soon as it was taken up the supply reel would start with a jerk, and this jerk would break the film. As a result, a special rewind supply spindle was made, as shown in Fig. 5, which worked very well and is incorporated in all the present cameras.

One of the difficulties encountered in photographic race-timing systems was the inability of the judges to make decisions from negatives. It was believed that enlargements on paper, provided that they could be made rapidly enough, would be worth while. The general requirements for a machine for developing the 16-mm. films and making the enlargements are rather unusual: It must be possible first of all to view a projected image of the finish of the race not later than three minutes after the film is exposed in the camera; and, within four minutes after the race, to place the paper enlargement in the hands of the judges. The rapid processing machine must be capable of handling lengths of film from a few feet up to sixty-five feet. The machine must operate under wide variations of temperature, and while originally intended for daylight operation, the present practice is to install the machine in a darkroom, which is darkened only during the period of picture taking and processing.

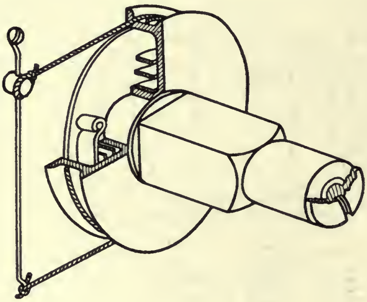

FIG. 5. Anti-loop-former device used on supply reel spindle.

It was planned to introduce the film into the machine in either of two ways: by mounting the camera reel upon the feed spindle of the developing machine; or, by feeding the film from the camera into a dry tank (Fig. 6) in which the film would be stored until drawn into the developer tank by starting the mechanism for lowering the rollers into the developer tank. In the original machine an attempt was made to feed the film directly from the camera into the developing tank, but this was found to be impossible because the speed at which the film was delivered from the camera was greater than that at which the developing tank could receive it. The addition of the dry tank overcame the difficulty, and such a tank has been incorporated as an essential part of the new machine.

The new machine is, in principle, the same as the original machine. It is constructed mainly of 18–8 stainless steel, synthane, and hard rubber to withstand the caustic developer and the hypo. The capacity has been doubled, making it possible to process as much as 65 feet of film. Refinements have made it more fool-proof and easier

to thread, and it is equipped with thermostatic control and pumps to maintain uniform bath temperatures of 85°F. A footage meter indicates to the processing machine operator how much film he must process. The operation of the enlarger has been simplified and accelerated by incorporating automatic paper expulsion and gauging equipment, while exposures are controlled by an electric timer, making possible a large number of prints in the shortest possible time.

Referring to the diagram of the present machine (Fig. 6), the essentials of its operation are as follows:

The machine is first threaded from the camera directly through to the crank for pulling the film. The camera is operated, photograph-

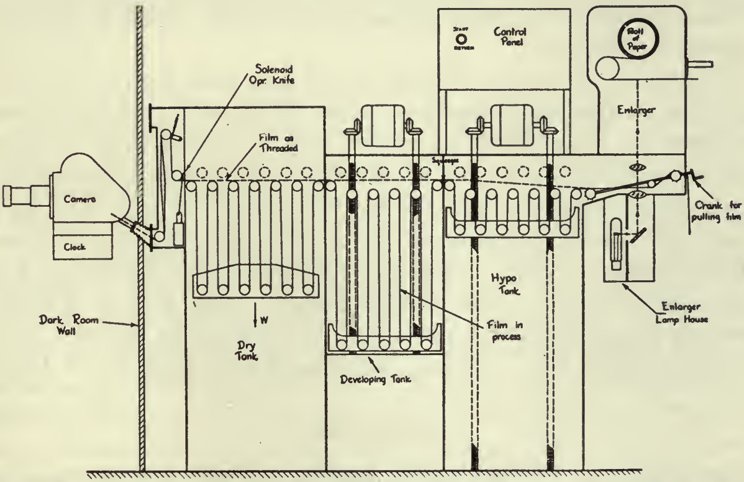

FIG. 6. Diagram of film path through camera, developing machine, and enlarger.

ing the finish of a race, and the excess film is stored in the dry tank, the rollers of which are lowered by gravity. Coincidentally with starting the camera, the processing machine is started, by pressing a push-button, and the rollers in the developing tank are lowered to the bottom by motor-driven screws. The film capacity of the developing tank is half that of the dry tank: thus, assuming a full dry tank, half the film will have been drawn from it when the rollers in the developing tank reach the bottom. The rollers in the hypo tank are started toward the bottom automatically when the developing tank

rollers reach the bottom. The rate at which the film is drawn into the hypo tank is the same as the rate at which it is drawn into the developing tank. The second half of the film in the dry tank is drawn out by the mechanism of the hypo tank into the developing tank, the film being squeegeed to remove excess developer as it passes into the hypo tank. When all the film has been drawn from the dry tank it is automatically cut by the solenoid-operated knife. At this point the developer tank contains the second half of the film, and the first half is in the hypo tank. The rollers of the hypo tank are halfway to the bottom, and continue on their way to the bottom until all the film has been drawn into the hypo tank. The film is not stationary at any time during the process, so that no trouble is encountered with rack marks. By using a caustic developer and a temperature of 85°F., development is completed in forty seconds. Eighty seconds is required for fixation.

The film is next shown through a film gate immersed in the hypo bath, and its image projected upon a ground glass to permit choosing the frames to be enlarged. A mirror is then removed from the light path, a shutter tripped, and an exposure made upon water-proofed paper stock. The print is cut from its feed roll and developed, rinsed, and fixed in trays in the darkroom. After fixation, the print is rinsed briefly in water. The enlargement is then run down a wire to the judges' stand. The 16-mm. negative may now be removed from the hypo and placed into a solution of sodium sulfate, to be stored until such time as it may be conveniently washed and dried.

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DISCUSSION

MR. DEPUE: How many feet of film are required to record a race?

MR. TUTTLE: The machine will process 65 feet of film. Most races require less than 15 feet. However, if the horses are strung out, as they sometimes are, and if time data are desired for each horse for future handicapping purposes, 50 or 60 feet of film may be required.

MR. DEPUE: How much time is required to obtain the visual results?

MR. TUTTLE: One minute and twenty seconds.

A NEW MONITORING TELEPHONE RECEIVER*

H. F. OLSON**

Summary.—*A high-fidelity telephone receiver having uniform response over a wide-frequency range is described. The new type of vibrating system compensates for the loss of low-frequency response due to the normal leak between the ear-cap and the ear. Uniform response is maintained at the high frequencies by employing a system of small effective mass reactance. Experimental data obtained with an "artificial ear" show the effect of the acoustic leak upon the response of various types of telephone receivers. Subjective tests are also described and data given which corroborate the tests with the artificial ear.*

The telephone receiver has been and still remains one of the most common means for transforming electrical pulsations into corresponding acoustical vibrations. The continued use of telephone receivers is due to the many advantages possessed by this type of sound generator. The sound is confined and does not disturb those in the immediate vicinity. The space and electrical power requirements are relatively small as compared to those of a loud speaker. The instruments can be carried easily from one location to another and connected in a moment. Because of these and other advantages, telephone receivers have been widely used for monitoring in broadcasting and sound motion picture recording, particularly in limited spaces and temporary locations. For these applications, telephone receivers are usually employed to check the quality and balance of the received sound. Therefore, it is quite important that the frequency response of the telephone receivers should correspond to the high-quality loud speaker systems that will ultimately reproduce the sound.

It is the purpose of this paper to consider: first, the requirements for a high-quality telephone receiver and, second, to describe a vibrating system for a telephone receiver that has a uniform response characteristic over a wide frequency range.

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* Presented at the Spring, 1936, Meeting at Chicago, Ill.

** RCA Manufacturing Co., Camden, N. J.

REQUIREMENTS FOR HIGH QUALITY

An ideal telephone receiver should produce the same sound pressure at the tympanum of the ear as the original sound. In other words, the introduction of the two electroäcoustic transducers, namely, the microphone and the telephone receiver, together with amplifiers and associated reproducing equipment, should not change the response-frequency characteristic of the sound pressure upon the tympanum as compared to the original sound.

When the head is immersed in the field of a plane sound-wave, the pressure at the surface of the head at the ears is a function of the frequency of the sound and the azimuth of the head with respect to

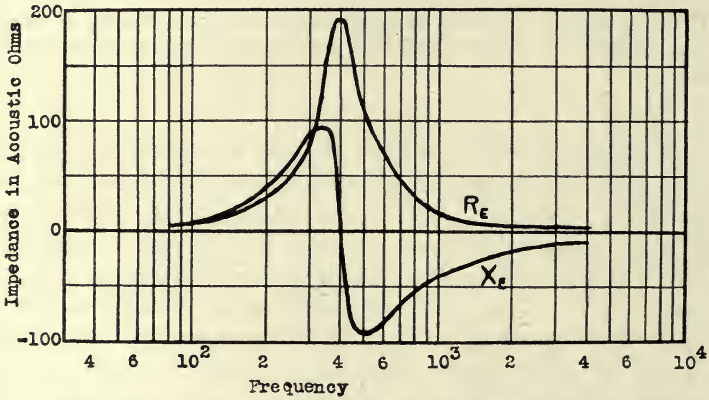

FIG. 1. Acoustic impedance of the human ear, viewed through the earcap of a telephone receiver (*after Inglis, Gray, and Jenkins*[3]).

the direction of propagation of the sound. It has been shown theoretically[1,2] and experimentally that below 1000 cps. the diffraction of the sound by the head is negligible. Furthermore, for this range the dimensions and configuration of the ear cavity are such that the pressure at the bottom of the ear cavity is the same as that at the surface of the head. At the higher frequencies, if the head is turned so that one ear faces the source of the sound, the pressure at this point at the higher frequencies is twice that in free space, while the shadow cast by the head results in very small pressure upon the other ear. Of course, the normal listening position is that of facing the sound, in which case the pressure at the surface of the head at the ears is practically the same as that in free space. In rooms, in addition to the direct sound, there is also the generally reflected sound. If all di-

rections of the reflected sound are assumed to be equally probable, there will be practically no frequency discrimination as regards any point on the surface of the head. The ratio of the pressure at the bottom of the ear cavity to the pressure at the surface of the head varies considerably from unity at the resonance frequency of the cavity. Of course, this resonance is modified by the introduction of the receivers. The relative importance of the factors discussed above will be apparent in any subjective tests. Assuming that the ratio of the acoustic input to the electrical output of the microphone and amplifier is independent of the frequency, the ratio of the volt-

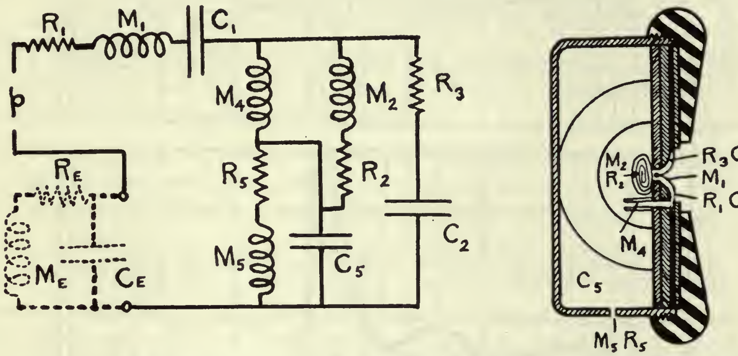

FIG. 2. Construction of the new receiver, showing the vibrating system and equivalent electrical circuit to deliver constant sound pressure to the ear cavity in the presence of a leak between the ear-cap and the ear. The equivalent electrical circuit of the acoustic impedance looking through the earcap is shown dotted.

age applied to the telephone receivers to the resulting pressure in the ear cavity should be independent of the frequency.

If a telephone receiver is very carefully sealed to the ear so that no leakage occurs between the ear-cap and the ear, the acoustic impedance presented to the receiver by the resulting cavity is practically a pure acoustic capacitance. For this condition, in order that the ratio of the sound pressure in the cavity to the applied voltage shall be independent of the frequency, the ratio of the diaphragm amplitude to the applied voltage must also be independent of the frequency. Receivers that employ soft caps, so that no leak can occur between the ear and the receiver, are uncomfortable when worn for long periods of time. Furthermore, considerable care must be taken to adjust the receivers upon the ears so that no leakage occurs.

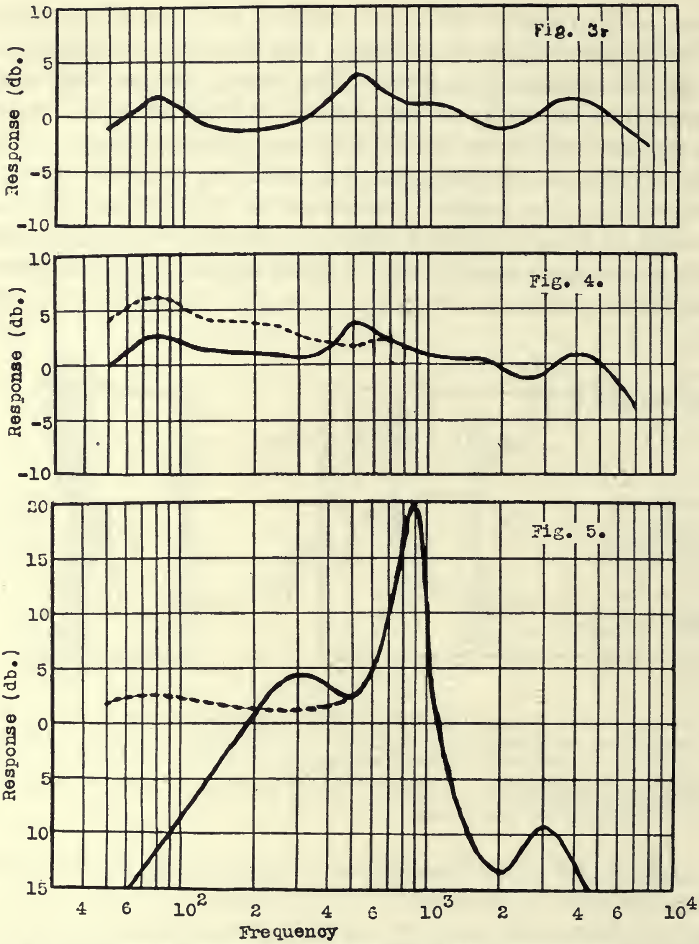

FIG. 3. Theoretically predicted response of the new receivers in conjunction with the human ear; computed from the circuit and constants of Fig. 2.

FIG. 4. Response-frequency characteristic of the new receiver, taken with the artificial ear; dotted curve shows response with a perfect seal ($M_E R_E = \infty$ in Fig. 2).

FIG. 5. Response-frequency characteristic of conventional bipolar telephone receiver taken with the artificial ear: solid curve, with normal leak; dotted curve, without leak.

In the case of telephone receivers with hard ear-caps, a leak occurs between the ear and the cap. The acoustic impedance presented to the receivers is considerably more complex than in the case of a per-

fect seal. Furthermore, the impedance varies with the manner in which the receivers are worn. Obviously, from a practical standpoint, the performance of the receiver should be independent of the leak between the ear and the cap. It is the purpose of the following section to describe a vibrating system that delivers constant sound pressure to the ear cavity, with a leak between the cap and the ear.

THEORETICAL CONSIDERATIONS

In order to design the vibrating system so that constant sound pressure will be delivered to the ear cavity by a constant applied voltage, we must know the acoustic impedance looking through the aperture in the ear-cap. This acoustic impedance has three components: namely, the (*1*) resistive and (*2*) inertive reactance due to the leak between the cap and the ear, and the (*3*) capacitive reactance due to the cavity. Investigations of the impedance looking into the aperture of the receiver cap have been made by Inglis, Gray, and Jenkins.[3] Graphs of resistive and reactive components of the acoustic impedance looking into the aperture of a telephone receiver are shown in Fig. 1. Examination shows that the impedance is positive and increases with frequency up to 400 cps.; between 300 and 500 cps. it is practically resistive; and above 400 cps. it is negative and decreases with frequency. To maintain constant sound pressure in the ear cavity under these conditions, the velocity of the diaphragm below 300 cps. must be inversely proportional to the frequency; between 300 and 500 the velocity should be independent of the frequency; and above 500 the velocity should be proportional to the frequency. This is a generalization of the requirements.

The system in Fig. 2, with properly chosen constants, delivers practically constant sound pressure to the ear cavity in the range from 50 to 7000 cps. This system consists of a *V*-shaped diaphragm M_1, driven by a straight conductor located in the bottom of the *V;* a suspension system, R_1C_1, supporting the diaphragm and aligning the conductor; a permanent magnet field structure; a cavity back of the diaphragm, R_3C_2; a bolt of cloth forming an acoustic resistance and reactance, R_2M_2; a tube, M_4; a case, C_5; and a hole in the case, M_5R_5. The equivalent electrical circuit of the acoustic system coupled to the equivalent electrical circuit of the ear is shown also in Fig. 2. The theoretical response, that is, the sound pressure in C_E for constant voltage applied to the conductor, can be computed from the equivalent electrical circuit. The theoretical response for a

certain set of suitable constants is shown in Fig. 3. This curve indicates reasonably uniform response from 50 to 7000 cps.

EXPERIMENTAL RESPONSE CHARACTERISTICS

A detailed discussion of telephone receiver testing has been given elsewhere.[4] In general, it may be said that the response-frequency characteristic of a receiver should indicate the pressure developed in an average ear at various frequencies by a constant voltage applied to the receiver. One of the variables to be considered is the normal leak that results at the ear-cap when the receivers are placed upon the head.

Artificial Ear Tests.—An artificial ear for testing telephone receivers should have the constants shown in Fig. 1. An artificial ear having these constants and a means for measuring the pressure at a point corresponding to the tympanum have been described elsewhere.[5]

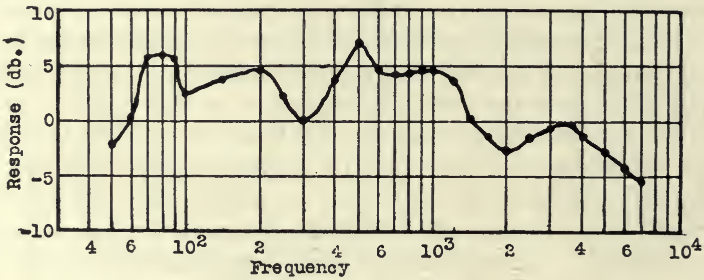

Fig. 6. Response-frequency characteristic of the new receiver. Response obtained by comparing with constant sound pressure in free space. Plotted points are an average of six observers.

The solid line in Fig. 4 shows the frequency-response characteristic of the new receivers taken with the artificial ear. The dotted curve shows the small change in response resulting from removing the leak at the ear, and indicates that the variation in response with various leaks is very small.

In Fig. 5 the solid curve represents the response characteristic of the conventional type of bipolar receiver taken with the artificial ear. The dotted curve shows the increase in low-frequency response obtained by removing the leak. These two curves indicate that in this type of receiver the low-frequency sensitivity becomes a function of

how well the units are affixed to the ear. Of course, the condition of no leak is practically impossible with hard ear-cap receivers.

Subjective Tests.—To confirm the characteristics as determined with the artificial ear, subjective measurements were made while the receivers were worn by various observers. A free progressive sound-wave is established by means of a loud speaker driven by an oscillator. The sound pressure at a distance of five feet from the loud speaker is measured by using a calibrated microphone, amplifier, and output meter. With the receivers removed, the observer listens to the sound at the point where the sound pressure was measured by the microphone. Next the observer places the receivers upon his head, and the

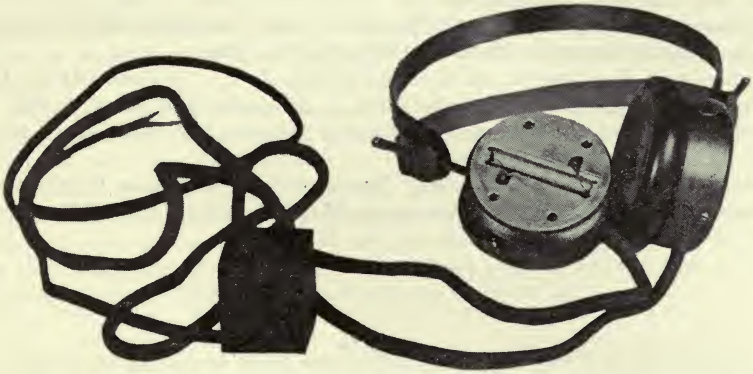

FIG. 7. The new telephone receiver, with one ear-cap removed to show the *V*-shaped diaphragm; the transformer for raising the impedance to the value suitable for bridging is at the end of the cord.

output of the oscillator is transferred from the loud speaker to the receivers by means of a suitable attenuator. The voltage across the receivers is adjusted until the intensity in the observer's ears is the same as the free-wave intensity from the loud speaker. This procedure is repeated at several frequencies, keeping the free-wave pressure constant. The reciprocal of the voltage across the phones required to match the free-wave sound intensity is proportional to the sensitivity of the receivers at each frequency.

Several persons independently conducted this test, and the average response-frequency characteristic as determined by the measurements is shown in Fig. 6. The maximal deviation from this mean curve for any individual was less than 3 db.

CONSTRUCTION

A photograph of the new telephone receivers is shown in Fig. 7. The size, shape, and weight are practically the same as those of a conventional bipolar telephone receiver. One ear-cap has been removed to show the *V*-shaped diaphragm. A transformer is located at the end of the cord to step up the impedance of the conductors to the value suitable for bridging. In this particular case the impedance is 2000 ohms, with a variation of only a few per cent over the entire response range.

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USE OF SILICA GEL IN AIR-CONDITIONING*

J. C. PATTERSON **

Summary.—*Dehumidification, or removal of moisture by adsorption, is a physical process, and not a chemical action. It is accomplished by gas equipment designed specifically for the purpose. Cooling, or the reduction of temperature, is a heat-exchange process requiring indirect surface coolers, through the tubes of which water or other refrigerants at relatively high temperature are passed by equipment selected specifically for the purpose.*

This independent control of humidity and temperature by distinctly separate pieces of equipment assures the maximum of flexibility and simplicity of control, and affords a practically limitless selection of conditions for satisfying individual ideas of comfort.

Some of the more important economies and mechanical advantages are: (a) the two separate and distinct operations are accomplished at comparatively high temperature levels, with corresponding economies; (b) the form of energy is used that is best and cheapest for each particular purpose; (c) low maintenance and depreciation results, due to the absence of reciprocating machinery in the dehumidifier, the durability of silica gel, and the reduction of the time of operation for each of the two primary components of the system—dehumidifying only or cooling only, or any combination, under automatic control to meet any and every need.

The application of heat energy to America's latest big industry, air-conditioning, is really the reverse of man's oldest achievement, the creation of artificial cooling as contrasted with artificial heating. It revolves about the fact that there are two essential phases of the problem, temperature control and humidity control. There is no definite relation between the magnitude of the two phases, because they depend upon widely variable factors, such as building construction, geographic location, character of use, occupancy, and many others.

There are two ways in which this two-part problem can be handled. One is the conventional way, in which a single piece of equipment is employed to accomplish the reduction of both the temperature and the humidity. Both are accomplished by cooling, but the reduction

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* Presented at the Fall, 1935, Meeting at Washington, D. C.

** Bryant Heater Co., Cleveland, Ohio.

of humidity is a by-product of the reduction of temperature, the magnitude depending upon the extent to which the temperature is reduced. In the conventional system, temperature reduction and humidity reduction are inseparably connected; one can not occur without the other, and the relation between the two is fixed practically within rather small limits.

To put it another way: In refrigeration systems it is common practice to cool a portion of the air to a temperature of 45–50°F., in order to condense some of the water vapor. In order to introduce the cooled air into the room to be conditioned without creating undesirable drafts, the air must be reheated, either by the expensive process of adding heat directly to the air or by mixing with the cooled air a portion of recirculated air that has not been cooled. The net result under ordinary conditions is that approximately 78 per cent of the refrigeration has been utilized in cooling the air and 22 per cent in removing water vapor from the air.

In contrast to the method just described, two pieces of apparatus can be used to accomplish the task: one capable only of dehumidifying, and nothing else; the other capable only of cooling, and nothing else. Each piece of equipment is a specialist at its own task. Each can operate independently of the other, and each can use the form of energy that is best for its particular purpose. If the cooling and dehumidifying are accomplished by separate pieces of equipment, each capable of being operated and controlled quite independently of the other, the result is that regardless of how widely the relation between dehumidifying and cooling may fluctuate, the flexibility of the combination is such that the desired indoor atmospheric conditions can be maintained regardless of the outdoor conditions and the indoor characteristics.

In this general scheme of air-conditioning, in which moisture is removed in one piece of equipment and cooling is done in another, it happens that heat is the cheapest and most flexible form of energy to use for removing moisture. A large part of the load is taken care of by heat energy. Thus it becomes possible to do a better job of air-conditioning, and at the same time it becomes possible to use a cheaper fuel in the process.

There are several moisture-removing materials that can be used for conditioning air which lend themselves to the application of heat energy. Of these silica gel has enjoyed the widest use and acceptance. Silica gel is a hard, porous substance, chemically similar to sand, but

structurally enclosing an infinitely great number of infinitesmally small pores. When moist air comes into contact with the silica gel, the pores of the material will adsorb the moisture much as a sponge absorbs water. Easily reactivated by heat, at approximately 350°F., silica gel can be used indefinitely: it never wears out.

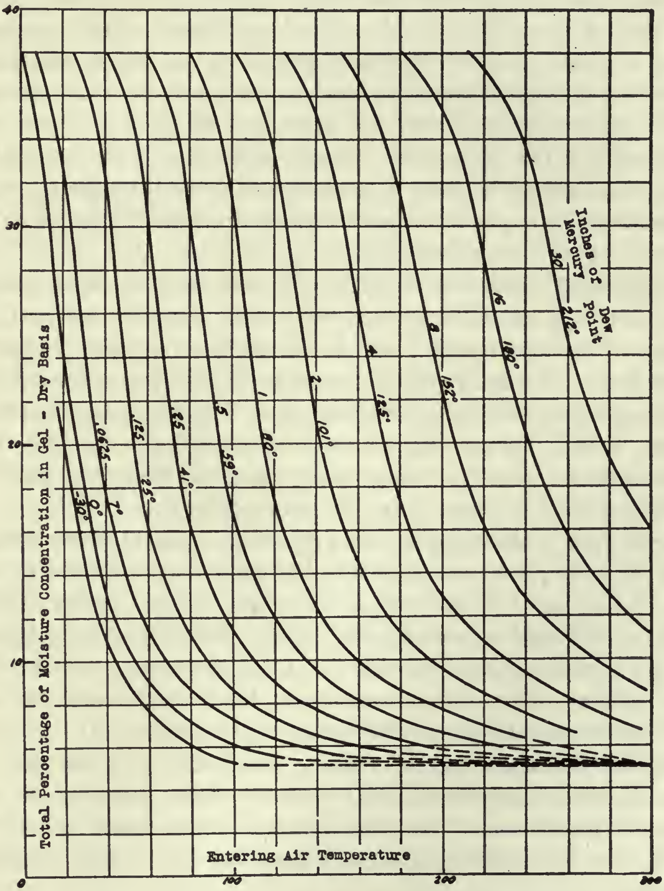

FIG. 1. Equilibrium curves: silica gel-water vapor.

Silica gel is a manufactured material obtained by the reaction of a soluble silicate, such as "water glass," and an acid, such as sulfuric; the two components being of definite concentrations and mixed in a definite ratio. The hydrosol of silicic acid thus formed "sets" in a definite time to a hydrogel (a jelly-like mass), which then is washed

free from excess acid and salts. The washed hydrogel is finally dried, sized, and heat-treated at a definite temperature. The resulting material is known under the trade name of "Silica Gel."

Chemically, silica gel is an analogue of a hydrated quartz (SiO_2x-H_2O), but structurally it is vastly different. Instead of being dense and impervious, it is light and highly porous, its internal structure consisting of a myriad of thin-walled capillaries whose average diameter is about 4×10^{-7} cm. (the diameter of the average molecule of a substance is 3×10^{-8} cm. or roughly one-tenth the diameter of the pores). It is estimated that one cubic inch of silica gel contains approximately 50,000 square feet of pore surface, and the internal pore volume of a granule is 50 to 70 per cent of the total volume. Normal commercial silica gel will adsorb approximately 40 per cent of its weight of water from saturated air.

In industrial applications, silica gel will adsorb vapor until the pores of the gel are filled to such an extent that the internal vapor pressure of the condensed liquid in the pores at a given temperature approaches as a limit the partial pressure of the vapor in the surrounding atmosphere at the same temperature. The gel is then reactivated by heat, usually by passing a stream of heated gas through the gel bed in order to raise the vapor pressure of the adsorbed liquid and thereby release it as vapor from the pores of the gel.

When vapor is adsorbed by silica gel, heat is liberated equivalent to the latent heat plus an additional amount of heat referred to as the "heat of wetting," in the case of silica gel. This combined heat is known as the heat of adsorption. Fig. 1 shows the equilibrium of silica gel water-vapor isopiestics, *i. e.*, constant-pressure lines. These curves indicate that the concentration of adsorbed water for a particular gel in equilibrium with water-vapor varies with the partial pressure of the water-vapor and the temperature of the gel. The curves represent constant partial pressure of the water-vapor in the air, or dewpoint lines. The adsorption of water-vapor by silica gel increases as the partial pressure approaches the vapor pressure at saturation.

The effect of the temperature of gel upon adsorption may be observed by following the dewpoint line for 59°F. At a gel temperature of 70°F., the gel will be in equilibrium at a concentration of 37 per cent; at 100°, 18 per cent; at 150°, 9 per cent; and at 200°, 6.5 per cent.

So, in effect, moisture is drawn into the pores and condenses within

them, releasing the heat that was latent in the vapor. This latent heat reappears in the outgoing air as sensible heat, which can be removed by a relatively warm cooling medium such as city water. Thus, the moisture removal is totally independent of sensible heat removal; for after the air is passed through the silica gel and is dried and warmed, it is cooled only to its original temperature. Only the moisture and latent heat have been removed. The air is now ready for any additional cooling that may be required.

In practice, a sufficient quantity of air is dehumidified, or dried, to counteract the increase of moisture in the space to be conditioned. This air is then mixed with a larger volume of air, and the whole cooled only sufficiently to neutralize the gain of sensible heat in the space to be conditioned. Since the removal of the moisture is accomplished not by excessive cooling, but by a purely physical process independent of the temperature, comparatively high-temperature cooling media, such as well water or city water at temperatures as high as 70°, may be employed to do the cooling. If water at a suitable temperature is not available, the cooling may be done by mechanical refrigeration, operating, not at very low temperatures such as 35° or 40°, but at higher temperatures, of the order of 60°. At such temperatures the refrigerating machines are capable of accomplishing any cooling that may be required at lower cost, both initial and operating. A refrigerating machine is a "heat pump"; and since the "hill" up which the pump must work is not "as long" with the higher suction temperature, the power consumption is less.

The present tendency in air-conditioning is toward higher dry-bulb temperature and lower humidity. There is also a demand for flexibility, to suit sharply varying load conditions, or the widely varying conditions of particular industrial processes. By separating the two functions, heat removal and moisture removal, great flexibility becomes available for meeting these widely varying demands. In some industrial applications it is necessary only to dehumidify, without any particular cooling. In such instances, the air is cooled only enough so that it can be discharged into the conditioned space at a temperature no higher than what would normally obtain without cooling.

It must not be construed that this method is new and untried. Numerous installations made according to this principle, both in the United States and in South America, have been in successful operation for a number of years and are in constant use today.

During the past year fifty-six installations have been made, ranging

in scope from residences and restaurants of moderate size to large department stores in which the total air-conditioning load expressed in tons of refrigeration approaches 500 tons*—these in the so-called "comfort field." For industrial or process air-conditioning, many installations have been made in such industries as pharmaceutical and drug, shoe manufacturing, cellophane, printing, and ceramic, in many instances maintaining relative humidities of 0.5 to 20 per cent or higher, as required.

In the great majority of these jobs, tap or well water (below 68°F.) is used as the means of sensible cooling, requiring no mechanical refrigeration. It is this combination of dehumidifying with silica gel and cooling with such relatively cold water that presents the most advantageous set-up from the standpoint of both initial and operating costs, low maintenance, and depreciation.

One objection that has often been presented to this variety of air-conditioning has been the additional space required for the silica gel dehumidifier. It is true that about 30 per cent more space is required for a silica gel installation than for the average refrigeration job, but this has not presented a serious handicap, once the advantages of flexibility and economy of operation of the combination system are understood. The extent of lower operating costs of this type of system over the more conventional type will depend upon the unit costs of power, gas or steam, and water, but as an average figure, the savings will be between 25 and 30 per cent.

To the author's knowledge, this method has not yet been applied in the motion picture industry. It would appear, however, that economy should result from using direct dehumidification, particularly in connection with film drying.

In any case, it would appear advisable to have some Committee of the Society make a study of this system of air-conditioning with a view to recording the advantages or disadvantages as compared with the more conventional refrigerating methods.

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* A "ton" of heat removal or a "ton" of refrigeration is a standard of heat extraction in a given time, or a standard of cooling effect. One "ton" of refrigeration is the cooling effect produced by the *melting* of one ton of ice at 32° in twenty-four hours. It requires 288,000 Btu to melt a ton of ice, and to do this in twenty-four hours requires 12,000 Btu per hour or 200 Btu per minute. Thus, one "ton" of refrigeration is equivalent to a heat removal of 12,000 Btu per hour or 200 Btu per minute.

DISCUSSION

MR. CRABTREE: I am sure that the Committee on Laboratory Practice would be glad to have further information on the engineering aspects of the use of this substance. There must be some real advantage in being able to dehumidify air and still maintain its temperature constant. The present tendency in laboratories is to dry film at as low a temperature as possible. Formerly, temperatures as high as 120°F. were used, but the modern practice is to use temperatures of 75° or 80°F.

It would also seem very desirable in theaters to dehumidify rather than lower the temperature of the air, because my experience is that in the summertime the theaters are too cold in relation to the outside temperature. If the necessary comfort could be obtained by dehumidification instead of by cooling, I think that would be a great advantage.

At what temperature does silica gel function most efficiently in dehydrating, and what temperature is necessary to remove the moisture from it?

MR. PATTERSON: From the curves, it will be noted that the lower the temperature of the air, the more efficiently can we adsorb by silica gel. In ordinary practice, of course, we get air around 95°, which is a very effective temperature at which to work.

Thinking in terms of water-vapor, the curves indicate that the concentration of adsorbed water for a particular gel in equilibrium with water-vapor varies with the partial pressure of the water-vapor and the temperature of the gel. We hear the claim that silica gel will remove up to 40 per cent of its own weight in water-vapor, and this is quite true. However, the question of balancing the economics of per cent of removal with time and quantity of gel is a determining factor. Shall we remove moisture equal to 40 per cent of the weight of the gel and take the period of time and quantity of gel required to accomplish it; or shall we remove 10 per cent over a shorter period and have a relatively greater frequency of cycles? As regards activation temperatures, as I have said, to remove the moisture from the gel, the air used for that purpose must be between 300 and 350 degrees. About 2.5 Btu are required in the activating air to release water-vapor equivalent to one Btu as latent heat of the released vapor. That is about the general relation.

We feel that the question of theater cooling is very pertinent. One reason why people are uncomfortable in the theater is that with the peak load occurring between seven and nine P.M., we also have a high wet-bulb temperature outside and a lower dry-bulb temperature than at noon. Thus we have the maximum moisture load from people as well as infiltration. Very often the refrigeration plant has insufficient capacity, with the result that it is doing primarily a cooling job, without sufficient dehumidification, and with a moisture load present that can not be coped with. The temperature is under control, but when the temperature is reduced without removing the moisture, the relative humidity is increased. That is what makes the place uncomfortable, and the result is a cold, damp feeling. We feel that the addition of a dry-air machine to such a system will do a great deal toward improving matters.

MR. CRABTREE: To what extent is the gel poisoned; or, is its efficiency impaired with use due to contamination by dust or chemical fumes?

MR. PATTERSON: I know of no instance in which silica gel has ever been

removed; that is, where the initial charge has ever been removed due to any loss in efficiency. We find some cases where it is necessary to put in filters for the incoming air, where the air is unusually dirty. Otherwise we might contaminate the gel to the point where the resistance is increased, and a sweeping action with unusually high heat would be required to burn off carbonaceous matter.

We have a counter-current action, the air to be dried going up, the heated air for activating purposes coming down. This counter-current sweeping action on the bed of gel naturally helps to keep the gel free from dust. But even here, if we have a very dirty condition to contend with, filters are used in the system. I know of no case where gel has been removed due to contamination, by either dust or chemical fumes.

THE PULL-DOWN MOVEMENT*

A. S. NEWMAN**

Summary.—*A discussion of the functions of the pull-down in relation to the characteristics of the materials of the film and the mechanism, and a brief description of some of the means employed for overcoming the difficulties.*

The function of the pull-down in the camera is to move the film accurately a definite distance without scratching the film or damaging the perforations. Perforation now is so uniformly good and the average film on the market so accurate as to pitch, size of perforation, and distance between the centers of the perforations measured across the film, that the difficulty of designing a pull-down movement to work the material accurately is quite small compared with the problem before perforation had attained its present accuracy; nevertheless, there are many outstanding discrepancies which at times cause difficulty in producing a satisfactory mechanism. The two materials, celluloid and gelatin, form a combination that is unstable under many conditions, the dimensions of which are likely to alter with changes of temperature and humidity. Gelatin is expanded very slightly by heat, but considerably by humidity; celluloid expands by heat considerably, but very slightly by humidity. Consequently, the combination of materials, which for our purposes should remain perfectly flat, is at all times prone to deformation.

Gelatin and celluloid also are both very capable of a grinding or cutting action, even on the hardest steel; not because they have any inherent grinding properties, but because they both form very good beds into which cutting material can become impacted, and so act upon metals in much the same way as emery paper. Celluloid becomes very easily charged with static electricity, and in that condition attracts dust and cutting particles. Gelatin sometimes, on the other hand, becomes slightly soft; and instead of cutting the material over which it slides, it adheres slightly, leaving some of its surface

* Presented at the Spring, 1936, Meeting at Chicago, Ill.

** London, England.

tightly attached to the metal, where it frequently accumulates to a great extent, probably because the friction raises the temperature at the point of accumulation so that the gelatin softens, and still more adheres. This accumulation, which probably consists of gelatin plus dust, is extremely difficult to remove completely from metal surfaces.

The electrical action of celluloid may sometimes become so great that sparks sufficiently bright to affect the emulsion may be produced. The engineer, therefore, in dealing with this problem, has a very difficult material with which to cope. Keeping the film flat under all conditions and producing a mechanism which, in spite of its accuracy, must deal with slight variations in the film, is consequently the most difficult problem in the design of pull-down mechanisms. Many systems have been suggested for keeping the film truly in the plane of the photographic image, which nowadays, owing to the introduction of wide-aperture lenses, must be much more exact than was previously the case.

Film in a dry atmosphere usually tends to become convex on the gelatin side, so that when the front edges are held against a flat backing, a very fine flat surface is the result; but when in a humid atmosphere the expansion of the gelatin surface produces the opposite effect, the problem becomes extremely difficult. A flat flexible surface curved in one direction so as to be slightly cylindrical, becomes almost exactly plane across any line at right angles to the direction of curvature, and gates have been made that curve the film in the direction of its length above and below the part to be exposed. Although this method to a great extent eliminates the difficulty, it also introduces friction at the bending points, and increases the likelihood of cutting away these points of the guide, or to cause the gelatin to impact on them.

In sub-standard machines a gate having a continuous curve has been used to advantage, the long curve causing less friction in the guides than the two small bends mentioned before. Nearly all camera gates are now provided with pilot pins for achieving exact registration of the film. Usually the pins are made to fit the perforation below the one used by the claw or other contrivance that moves the film. For very exact work, such as rear projection, the pilot pin in all machines—camera, printer, and projector—should occupy the same position relative to the picture. Pilot pins are either fixed or movable; that is, they either enter the film, or the film is moved up and down, on and off the pins. When pilots are made to move, the

guides in which they slide must be carefully watched to see that the wear does not allow play of the pins, to the detriment of accuracy; and all pilots should be examined from time to time and new ones substituted as soon as they become small as the result of wear.

In order to hold the film in position for successive movements, gate friction is important in many cameras, and is still used in some. With a badly worn dowel pin, steadiness of the film may be improved by gate pressure, the registration taking place at one edge of the perforation only. This is especially the case in projectors in which the Maltese cross is slightly worn. The surfaces that press upon the film to produce the friction require very careful attention to prevent scratching the surfaces or packing up the gelatin, and generally require frequent cleaning. Some gates are produced having no friction except such as may arise from inequalities in the thickness or deformation of the surface of the film. Gates are also made in which the pressure surfaces are separated during the time of movement of the film and brought together by a spring or mechanical means, clamping the film while in the position of rest. As to the relative advantages of the three methods many opinions exist. The continuous pressure flattens the film to the focus plane extremely well, but is liable to "scratching" and "packing." The fixed method is less liable to packing and scratching, but does not keep deformed film so exactly in the focus plane. The clamping method is not likely to cause either packing or scratching, but has the disadvantage that any small particles adhering to either surface may cause the clamping action to occur before the film has quite finished its movement. This, however, seldom happens sufficiently to cause trouble, because, should it occur in one frame, it is probable that the film in its movement will sweep the obstruction away before the next frame is in position.

The surfaces of the gate against which the film slides are difficult to keep in perfect condition, owing to the cutting action of the film. Many substances have been tried but *hard* steel is usually used. Experience seems to favour a nickel alloy, which, although much softer than hard steel, appears to withstand the wearing more effectively. The author has tried also surfaces and edges of quartz, cornelian, agate, jade, and black onyx, but all these materials have shown evidences of cutting.

Many mechanical movements have been designed for the purpose of moving the film a definite distance from frame to frame. Camera mechanisms are driven almost universally by claw movements. In

most cases nowadays they are actuated by cranks, because the crank is a mechanical device especially suitable for moving reciprocating parts, in that it passes through two dead positions, at which the connecting rod is in a straight line between the moving part, the crank pin, and the crank center. Rotating the crank gradually increases the speed of the moving part until the crank is at right angles to the dead center; the speed then gradually decreases until the next dead point is reached. The acceleration of the moving part is not exactly the best possible, but it is sufficiently so for all practical purposes. The length of the connecting rod is also a factor, because when the slide in which the moving part runs is in a straight line with the crank center, the positions of quick movement are not quite at right angles to the dead center and depart more from that position as the length of the connecting rod becomes shorter. Also, when the slide is not in the same straight line with the center, considerable deviation of the dead points occurs, which can be utilized in some cases by making the time of the acting stroke of the claw less than the time of the return stroke, so that the change time may be shortened.

Crank movements are so numerous and varied that it is useless to elaborate on special ones. Provided that certain definite conditions are fulfilled, it is quite easy to design a large number of arrangements, any of which will work well. Crank movements are often suited to confined spaces, and frequently cams have been used for producing the necessary reciprocating motion. The first Lumière machine was an example of this class of movement. With a cam working against a spring, almost any acceleration can be produced; or with a cam and a suitably shaped opposing cam, the same may be effected without a spring. To do so accurately requires extremely careful designing and very high quality workmanship if the machine is to work quietly. Springs such as would be used in movements of this description are very unreliable because at the speed of, say, 24 frames per second they apparently become sluggish during continuous running, although they apparently also recover after quite a small period of rest.

The writer holds a great preference for pin-joints or eccentrics for driving reciprocating parts (an eccentric, after all, is merely an enlarged pin-joint). When cams are exactly fitted against their levers or slides, they are very likely to bind if a small amount of foreign matter gets between the surfaces. The action is comparable to that of a ball clutch; and in a well fitted cam action, foreign matter of the size of 0.001 inch may cause trouble. The conditions to be fulfilled in

designing a pull-down movement in which there are reciprocating parts are as follows:

(*1*) *As to Treatment of the Film*

It should move the film a definite distance at each stroke.

It should effect the movement without damaging the film.

The gate-pressure should be necessary only for the purpose of holding the film flat.

(*2*) *As to Mechanical Aspect*

Its parts should be balanced so as to eliminate vibration, or should be so light that the vibration imparted to the machine is so small as to be negligible.

It should operate with a minimum of friction, and be capable of running a long time without requiring frequent lubrication.

(*3*) *As to Practical Aspect*

It must be sufficiently robust to do its work efficiently, and light enough to cause little difficulty in balancing its parts.

Its joints, slides, or cams should not be likely to bind or lock as a result of the accidental introduction of dust or particles of foreign matter.

ACTION IS NEEDED*

F. H. RICHARDSON**

Summary.—*A recently published editorial by a well known writer of the industry is quoted, in which the importance of excellence of projection is stressed. The possibility is discussed of realizing beneficial results through the coöperation of the SMPE; and the opportunity for educational work with organizations representing the projectionists is pointed out, and the manner in which such educational work might be carried on effectively is discussed.*

As the immediate reason for this paper, the three papers appearing in the March, 1936, JOURNAL may be cited, *viz.*, "Technical Advances in Soviet Russia," "The Motion Picture in Japan," and "The Motion Picture in India." In each of these papers much stress is laid upon technical advancement. But in none of them do we find even so much as one sentence directing attention to the fact that incorrect or inferior presentation of technical perfection, as exemplified in the finished motion picture film, operates to reduce the value of such technical improvements, in many instances practically to nullify them, so far as has to do with thousands of theater audiences who are the purchasers of the product of the industry.

This is a condition that has existed from the beginning. It is one that is largely ignored by producers, technicians, and almost everyone else. It is a condition that should surely have the undivided attention of this Society until such time as its importance is realized and adequate steps are taken for its remedy.

The following is quoted from the writings of Terry Ramsaye:

"When St. Luke (Chapter 18, verse 25) was trying for a metaphor denoting the extremely difficult, he wrote: 'For it is easier for a camel to pass through the eye of a needle,' *etc.*

"That probably referred not to a sewing needle, but was a picturesque designation of the narrow-slitted, one-man side gates of the walled cities of Syria.

"However, putting a camel through a needle's eye is no considerable

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* Presented at the Spring, 1936, Meeting at Chicago, Ill.

** New York, N. Y.

undertaking as compared to the performance of the motion picture projector which puts perhaps a billion and a half dollars' worth of entertainment in the United States alone each year through an aperture about the size of a postage stamp.

"No other art or industry in the world narrows down the essence of its success in performance and delivery to quite such a needle's eye as that through which all the motion pictures must pass.

"The job is done in the continuous miracle of the screen by a man and his machine—the projectionist and his projector. They both have to be endowed with a competency close to perfection.

"The theater may have acres of carpets, miles of seats, tons of machinery, and army of staff, but the supreme essence of what it is all about goes through an opening 0.600 inch high and 0.825 inch wide—the opening in the projector aperture plate. Back of that tiny opening stands the whole of the great production plant from Hollywood to London, and in front of it is the fate of the box-offices of the world.

"Projectionists have become so competent, machines so perfect in function that we often tend to forget about projection. But after all it is not, in all its perfection, automatic. High standards of projection may be maintained only by the exercise of unrelenting vigilance, and constant, unwavering attention to that needle's eye of the industry. One-thousandth of an inch, one-hundredth of a second, matter vastly at the needle's eye, and again out upon the screen. In a considerable number of theaters still, despite all the facilities available, projection is yet to be brought up to the highest attainable standards.

"A great deal has been set down about refinements and enchantments of sound recording in wide-range and high-fidelity. Much has been said about the necessity of bringing sound reproduction channels up to the capacity required to deliver all that the sound-track carries. Meanwhile refinements of the camera lenses and photographic emulsions, studio lighting, and actinic values have also given to today's negatives and prints a new range of values in tone and quality that can be delivered to audiences only by the best equipments and projectionists' skill."

Consider Mr. Ramsaye's intent. We are asked to give thought to the relation that equipment, skill in projection, and technical advancement bear to each other, and what inefficiency can do, and does, to the splendid results attained in the modern production studio. Having done so, is it not clear that the Society should concentrate a greater

part of its energy to assuring the public that it will receive, in screen image and sound, what the studio has placed upon the film? The perfection that has been recorded in the film should be delivered to the theater patrons.

While it is true that compared with some years ago projection has advanced vastly; still, the advancement is, viewed as a whole, far behind the advancement in picture and sound recording, due almost, if not wholly, to the failure or refusal of many exhibitors to maintain their equipment in as good condition as possible, and their further failure in not insisting upon thorough competency in the projection rooms.

The subject of arousing more interest in projection among the exhibitors is one that should have the attention of the Board of Governors. The Society might also look into the possibility of enlisting the coöperation of the IATSE and MPMO in respect to inducing its various units (unions) to assist their projectionist members in improving their technical knowledge of projection.

It is certain that the projectionists' organizations will be found quite willing to confer with the Society and to coöperate. Such a plan, properly carried out, might produce tangible results. It might be well to have a committee of the Society appear before the IATSE at one of the national conventions, to urge the duty of the IA to raise its projection membership to the highest possible standard of both practical and technical knowledge. Such a committee would assuredly receive serious attention and the effect would be very beneficial. The IA now issues two official bulletins and might, through them, accomplish much. Some of the unions have started "schools" for projectionists, but although their beginnings were generally promising, they soon died out from lack of interest. I know of none that has existed for any extended period of time.

Many years ago the American Projection Society was organized. Its chief purpose was education in projection. For a time it gave promise of becoming permanent and producing tangible results. In fact, through its period of activity it did produce excellent results, but finally it also failed, except for its one headquarters branch, which still exists in New York and is accomplishing a considerable amount of good work. In Toronto, the branch of the APS that existed there before (ten branches were organized in various cities before the depression) has been revived under another name, and it is proposed to establish branches in all Canadian cities in which unions exist.

By working with the unions, as suggested previously, the Society could do much toward creating a very effective educational organization. Lectures could be arranged and forwarded in mimeographed form at intervals to the various unions, with whatever slides and illustrations might be necessary. Lecturers could also be supplied. Equipment manufacturers would undoubtedly be glad to supply papers dealing with their own equipment—projectors, lenses, arcs, mirrors, sound apparatus, *etc.*

It would be impracticable to build up such an organization independently of the unions, however; and to build it within the union might mean restricting it to only union men, although it is possible that consent might be obtained to admitting a limited number of non-unionists. There is urgent need for such an educational organization that will do effective work and be a lasting institution, and it is hoped that the Society will take active cognizance of the need.

NEW MOTION PICTURE APPARATUS

During the Conventions of the Society, symposiums on new motion picture apparatus are held, in which various manufacturers of equipment describe and demonstrate their new products and developments. Some of this equipment is described in the following pages; the remainder will be published in subsequent issues of the Journal.

RECENT IMPROVEMENTS IN THE VARIABLE-WIDTH RECORDING SYSTEM*

B. KREUZER**

At various times since the advent of sound motion pictures it has been deemed advisable to describe the basic RCA film recording system. These descriptions have followed the introduction of new elements into the system or new designs of existing units. These improvements have been the outcome of constant laboratory research and development work, augmented by experience in the field. An endeavor has been made to improve the quality and at the same time retain, as a compact unit, an equipment that is rugged, has few adjustments, is simple to install and operate, and which, because of the planned construction, can be efficiently modernized as further developments are made.

BASIC SYSTEM

Before proceeding to the description of the new system, a brief analysis of the equipment will be made. Fig. 1 is a greatly simplified drawing of the recording system. The signal is generated in the microphone, and is amplified before being fed into the mixer. Frequency attenuators in the mixer offer the choice of two degrees of low-frequency and one degree of high-frequency attenuation for each mixer position.

The output of the mixer is fed into the main recording amplifier where the signal level is raised to the degree necessary to operate the galvanometer located in the optical system. The neon volume indicator is operated at this signal level through a resistive network.

Because the internal impedance of the galvanometer varies with frequency, the voltage at the galvanometer terminals does not remain constant with frequency when a constant internal voltage is generated in the vacuum tubes of the output stage. For this reason a tertiary winding is provided in the interstage trans-

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* Presented at the Spring, 1936, Meeting at Chicago, Ill.

** RCA Manufacturing Co., Inc., New York, N. Y.

former preceding the output stage, from which winding the noise-reduction amplifier and the monitor amplifier derive their input.

The signal at the input of the noise-reduction amplifier is first amplified and then rectified. The resulting output is a d-c. signal corresponding to the audio-frequency signal volume. This varying direct current passes through a separate biasing winding in the galvanometer, and determines the mean position of the galvanometer mirror and consequently of the light-beam falling upon the slit in

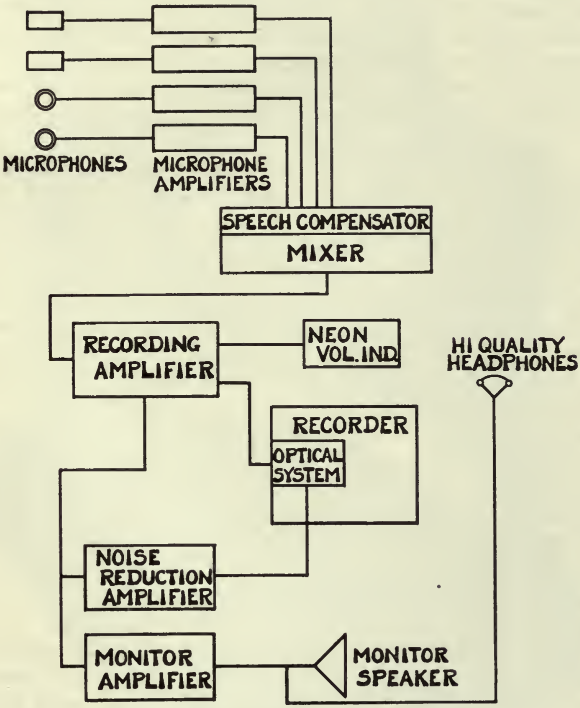

FIG. 1. Elements of recording system.

the recorder. Since the light-beam projects a triangular image, the movement of the mean position of the beam determines the width of the beam exposing the film through the slit. The current in the modulation winding of the galvanometer causes a deflection of the galvanometer mirror in accordance with the signal represented by this current. This deflection occurs about the mean position of the light-beam, and results in a sound-track of varying width whose greatest width corresponds to the maximal amplitude of the signal being recorded. The noise-reduction biasing current causes the mean width of the beam to be sufficiently great, by a small margin, so that no distortion of the recorded signal can occur. A timing circuit is an integral part of the noise-reduction amplifier, and determines the time required to widen the light-beam to accommodate signal

amplitudes and to narrow the light-beam when no signal, or a signal of lower amplitude, is being recorded.

A sound-track positive printed from a negative recorded in this fashion contains a minimum of clear space for this type of sound-track, and considerable noise-reduction is therefore achieved. It is interesting to note that the opening or widening time is sufficiently rapid not to distort the beginnings of sounds, but is sufficiently slow not to cause thumps in the reproduced sound. The advent of greater low-frequency response in theater equipment required a lengthening of the time, which is now about 0.01 sec. The closing or narrowing time is made sufficiently long so that the lowest frequency to be recorded will not modulate the biasing current. This time is 0.22 second.

When "push-pull" sound-track is recorded, the entire noise-reduction system is eliminated, further increasing the compactness and simplicity of the recording system.

In the recorder the film is propelled by the well known magnetic drive, and is exposed while passing over a drum so designed that no fluctuations in speed can occur. This recorder, like its prototypes already in use in the field, is constructed according to a unit plan, allowing for the replacement of individual units as new developments are made. That this has been a practicable plan is evidenced by the fact that all previous models of the recorder since the advent of the magnetic drive have easily been changed to accomplish noise-reduction, symmetrical high-fidelity recording, push-pull recording, and ultraviolet recording, as the developments occurred. Indeed, only a very small change is required to accomplish variable-density recording, if for any reason this might be desired.

The monitor amplifier is a-c. operated, and supplies signal to two unique transducers. The first of these is an electrodynamic loud speaker, which is notable for an amount of low-frequency response not usually associated with a loud speaker of such small size. The second is a set of high-quality head-phones, which are light and rugged and whose response is not a function of their position upon the wearer's head.

COMPONENT UNITS

Microphones.—Ribbon microphones are furnished, in two types: the first intended for recording music and distant dialog, is of the velocity type; the second, for outdoor use in general and for medium and close-up dialog in the studio, is of the pressure type. These microphones have become so familiar because of their general acceptance for broadcast use that space and time need not be consumed by additional descriptions of them.

Microphone Amplifier.—The microphone amplifier has two stages having a total gain of 47 db. The input and output impedances are each 250 ohms. A three-pole Cannon receptacle is provided for the cable from the microphone. A larger five-pole receptacle makes the necessary connections for the battery supply and the output signal. The microphone amplifier can be mounted upon a rack as a unit accommodating as many as four microphone amplifiers in a horizontal row; or it can be isolated and used upon the stage as a remote booster. It may also be plugged directly into the mixer console desk. The external appearance of the phototube preamplifier used to amplify the signal from a film phonograph is identical with this amplifier.

Compensation for film-transfer loss is accomplished in the grid circuit of the second stage of the microphone amplifier. Resistance and capacity elements are employed. The same procedure is followed with the phototube preamplifiers. The use of compensation in this medium-energy, high-impedance circuit allows the use of compact circuit elements.

FIG. 2. Mixer console desk (front).

Mixer.—Fig. 2 shows the mixer console desk, in which are incorporated four mixer positions, the master control, the individual frequency attenuators, and a volume indicator of the copper-oxide type, the type most frequently used with mobile recording systems (truck mounted) in which the heavier current drain of the neon type of indicator may not be desired. Individual switches are provided for controlling the battery supply to the microphone amplifiers, which may be located adjacent to the unit or at other points, as mentioned previously. The mixer controls are of the bridged-T type, having only two moving contacts. Careful

design and choice of contact materials assures a negligible noise level from these contacts, and one-hole mounting assures easy accessibility for cleaning. The impedance of each control is constant over the attenuation range. The individual and master pads are divided into nineteen accurately calibrated 1.0-db. steps. The accuracy of calibration of these steps is an invaluable aid in making measurements of gain or frequency characteristics, or in calibrating volume indicators. A volume control is also mounted upon the mixer base to regulate the volume in the high-quality head-phones. A table model mixer having the same electrical equipment is also available.

Fig. 3 shows the rear of the console. A cushioned shelf with individual slides for the microphone amplifiers can be seen. This is a feature not possessed by the small table model. Both table model and console mixer have been designed for use either upon the set or in a recording booth. From the start of the design work the system has been planned so it may be easily changed from set to booth mixing merely by moving either type of mixer to the alternative location and plugging in a few cables. It is believed that the table model mixer will find its greatest application with mobile recording units, and that the mixer console desk will be most useful in connection with studio recording. Both units are finished in an attractive gray crackle with chromium trim, and all the units of either type of mixer are made accessible by pressing concealed latches.

FIG. 3. Mixer console desk (rear).

Each of the inputs to the mixer has an impedance of 250 ohms. The output impedance is 500 ohms. The insertion loss of the mixer is 10 db. This is a lower value than is usually associated with a mixer of this quality, and is provided by suitably designing the attenuating networks and inserting an impedance-matching transformer between the individual attenuators and the master.

The height of the mixer console desk has been carefully determined to afford maximum comfort and convenience of operation to a man seated in the collapsible type of canvas chair so frequently found on studio sets.

Volume Indicator.—Fig. 4 shows the neon volume indicator. Tiny neon lamps furnish an accurate, easily read, logarithmic scale, making the instrument an invaluable means for remote volume indication. The device has no appreciable lag over the audio-frequency range, and is an ideal peak voltmeter. A tiny triode of the "acorn" variety is associated with each neon lamp. These vacuum tubes are located at the rear of the unit, and are instantly accessible when the unit is swung out upon the heavy hinge visible at the right of Fig. 4. It is interesting to contrast the compactness of this unit with the undesirable bulk that would have resulted from using vacuum tubes of conventional size.

The filaments may be excited by alternating current from a filament trans-

former (3.2 amperes, 6.3 volts) or by direct current from the amplifier batteries. The anode supply is obtained from a bleeder resistor in the a-c. operated monitor amplifier. If supplied from batteries, 180 volts are required. Slide-wire adjustments for calibrating the neon lamps are accessible from the front, but such calibration is necessary only when replacing lamps or tubes. An over-all gain control is located on the front panel for calibrating the unit as a whole with respect to the particular recording circuit with which it is to be used. Experience has shown that the life of the neon lamps under such intermittent use is practically endless. The vacuum tubes are operated at reduced voltages to increase their life.

The input impedance of the neon volume indicator is 30,000 ohms, and it is therefore a bridging load for all the low-impedance points in the recording system. A volume range of 45 db. below and 3 db. above full track modulation is available for accurate observation.

Amplifier Rack.—The amplifier rack is shown in Fig. 5, the small panels covering the vacuum tube shelves having been removed. The smooth front aspect of

FIG. 4. Neon volume indicator.

the units is worth noting. All units are removable from the front. The component parts of each amplifier are mounted upon the front panel, which swings out upon the heavy hinges visible at the right. In this way five of the six sides of each amplifier are immediately available for inspection. On the sixth side (which is the front panel) is located the vacuum tube shelf, which is opened from the front by removing the cover panel, held by two thumbscrews. Any amplifier may be temporarily removed from the rack quickly and conveniently by "splitting" the hinges referred to above, allowing the outer frame and the heavy shield to remain in place. In addition to providing accessibility, this form of construction possesses several other advantages. It allows the more permanently placed shield to be rigid and heavier than usual, making it a better electrical shield. The lead-covered cables remain permanently connected to the terminal strips provided at the rear of the shield, and the amplifier racks may be placed against the side wall of a truck body or built into a studio wall, since it is never necessary to have access to the rear when the equipment is permanently installed. Fig. 5 indicates the shallowness of the individual units. On the back of the rack, at the bottom, is a distribution panel for use when the rack is employed for portable or mobile work. This distribution panel allows all connections to be made quickly and correctly by means of standard plugs and cables from a conveniently located wall or floor box.

Recording Amplifier.—In the recording amplifier, wire-wound resistors are used exclusively. Two gain controls are provided. One, at the left of the amplifier panel, is accurately calibrated in fifteen steps of 2.0 db. each and five steps tapering to a total of 60 db.; and the other, at the center of the amplifier panel, has two steps of 14.0 db. each. The precise construction of these units makes accurate operation very simple and is an aid in making measurements of gain and frequency characteristics. The over-all gain of the amplifier is 80.0 db. and the circuit is designed so that the first stage to overload is the output stage. This occurs at a level of 800 milliwatts, which is double the power necessary to operate two recorder galvanometers. The input impedance of the amplifier is 500 ohms. Output impedances of either 250 or 500 ohms are available. The tertiary winding previously described is termed the "interstage output," and may be loaded with 5000 ohms. The necessary single meter and metering jacks are also mounted upon the front panel. Arrangements have been made for operating on a filament supply of either 6 or 8 volts, and a plate supply of either 180 volts or 225 volts if self-biasing is desired. Connections for the correct filament supply are established by choosing one of two positions for the filament fuse. Connections for the correct plate supply are established by including or omitting a 45-volt block of grid-biasing batteries.

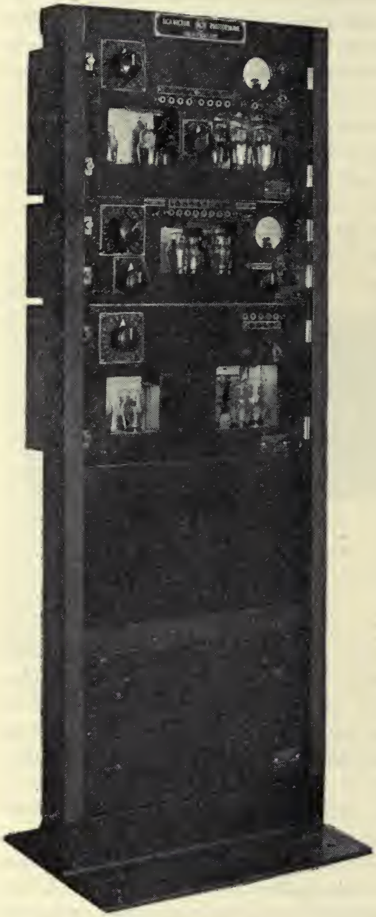

FIG. 5. Amplifier rack (tube covers removed).

Noise Reduction Amplifier.—The noise reduction amplifier has the same constructional features as the recording amplifier just described. Metering jacks are provided into which the cord from the voltmeter on the recording amplifier may be plugged. A meter on the panel, in the output circuit, measures the current in the galvanometer biasing winding. Buttons are located upon the front panel for disconnecting either the audio signal or the biasing current for test and adjustment purposes. Two gain controls are provided, for adjusting the clearance or margin of the noise-reduction system. One is accurately calibrated in nineteen steps of 0.5 db. each, and the other has two steps of 6.0 db.each.

Monitor Amplifier.—The a-c. operated monitor amplifier is in reality an all-purpose power amplifier. Although used for the monitor, it is also ideally suited for driving either a film or a wax recorder when several such machines are operated on one recording system. The volume control is accurately graduated in fifteen steps of 2.0 db. each and five steps tapering to a total of 60 db. The over-all gain is 38 db. The input impedance is 30,000 ohms, and the amplifier may therefore be bridged across any of the low-impedance circuits in the system. Output impedances of 250 and 500 ohms are available. A tertiary output winding, as in the recording amplifier, is also available. An undistorted output of 3.9 watts is obtained. The amplifier can supply excitation to the field of a loud speaker, and anode supply for the neon volume indicator.

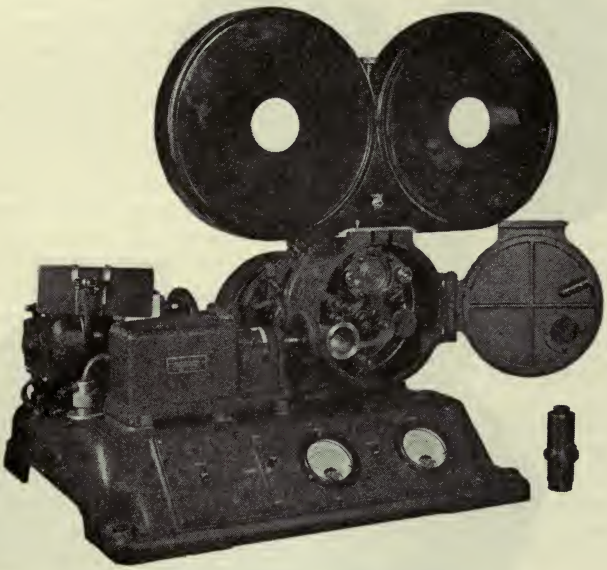

FIG. 6. Film recorder (front).

Distribution Panel.—When an amplifier rack has to be moved from one point to another, the distribution panel mentioned previously is used to consolidate all the connections. Plugs and receptacles have been employed of the types that are rugged and have demonstrated over a period of years their ability to remain free from contact difficulties. The receptacles are plainly marked, and the plugs can fit into only the receptacles for which they are intended. When an amplifier rack is permanently installed this unit is replaced by a conduit strip and terminal block.

Monitor Loud Speaker.—In the monitoring loud speaker an electrodynamic cone mechanism is mounted directly behind a small grille at the top. The front of the cone supplies the high-frequency response so necessary for careful monitoring. The rear of the cone is coupled to a folded-horn construction in the body of the box, terminating in a larger grille. This acoustic path supplies the low-frequency response desirable for judging the quality of male dialog, orchestral bal-

ance, and sound effects. It is also of great help in detecting any low-frequency noises that may penetrate because of ineffectual studio isolation. The monitor is sufficiently compact for suspension mounting in even a very small monitoring booth.

High-Quality Headset.—The high-quality headset contains small transducers of the pressure ribbon type that are compact and quite light, and are therefore comfortable for the wearer. It is interesting to note that their response is not a function of the loading supplied by the human ear. A small transformer is located at the junction of the cords from the two units of the headset. The frequency

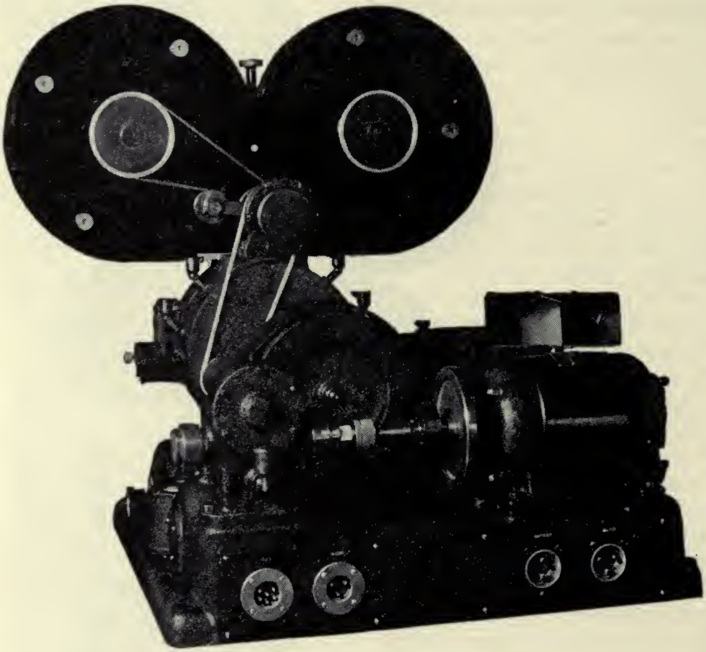

FIG. 7. Rear view of recorder.

response is flat within ±3.0 db. between 60 and 6000 cps. The response decreases between 6000 and 7000 cps., and from 7000 to 10,000 cps. is an average of 10 db. below the 1000-cycle response. Use of this means of monitoring allows a much closer check on the sound picked up by the microphone, because the reverberation of the monitoring booth is entirely eliminated. This is of particular value to the recordist in reducing the effects of high-frequency reflection so commonly experienced with the "hard" sets in general use.

Recorder.—The recorder, shown in Fig. 6, is the latest model of the magnetic-drive type. A single sprocket acts both as pull-down and take-up. All sprocket flutter and variations of speed are removed from the film at the point of exposure to the light-beam, as a result of the close contact between the film and the mag-

netically driven drum, effected by a synthetic rubber roller, and the compliance of the loops formed by the film before entering upon and after leaving the drum. Provision is made for placing a viewing telescope in the hollow interior of the drum, by means of which the light-image may be viewed from the under side of the film through a small aperture in the drum. This is an invaluable aid to focusing and aligning the track, and even affords a convenient means of monitoring during rehearsals. If the recorder is operated without film and the microscope is in place, the instrument may be used as an oscillograph, since the persistence of vision of the eye causes a continuous picture of the intermittent flashes in the aperture in the drum. Using the recorder as an oscillograph is a very excellent way of checking the recording system as a whole for such characteristics as noise-reduction margin, wave-form, frequency response, *etc.*

The rear view of the recorder, Fig. 7, shows the flywheel on the end of the drum shaft. The shaft is ground with great precision, and runs in a carefully fitted bearing. The flywheel, drum, and shaft are entirely free from the rest of the driving mechanism and are coupled to it only through a magnetic air-gap. If the magnet is not energized, no rotation of the drum will occur when the recorder is operated. All controls for regulating the exposure lamp current and the field current, as well as the motor switch, are located upon the recorder together with the lamp current and field current ammeters. A three-position key upon the front panel allows for normal operation, for disconnecting both the modulating and biasing coils of the galvanometer, and for interrupting the modulation current only.

The unit plan of construction has been followed in the mechanical design of this recorder also. Regardless of the frequency of the motor supply or whether this supply is synchronous or Selsyn, the recorder head remains unchanged. It is necessary only to change the motor and the gear-box visible in the photograph to accommodate the recorder to these various forms of supply.

The film magazine take-up drive, visible also in Fig. 7, is a viscous drive mechanism consisting of two cones, whose sections are concentric, separated by a liquid film. To insure a negligible change with temperature, a liquid possessing an unusually low temperature-viscosity gradient is used. Smooth, uniform rolls of film are assured in the take-up chamber of the magazine. The tension is not sufficiently great at the start of the reel to jerk the film, but is sufficient to handle the load of the full reel.

Optical System.—A 7.5-ampere incandescent lamp is used as the light-source for ultraviolet recording. The effective slit width is 0.25 mil, obtained by using a relatively large mechanical fixed slit (0.0015 inch) and an objective lens system. The familiar triangular aperture for symmetrical variable-width recording and the double triangular aperture required for push-pull recording are housed in separate condenser lens barrels. Either aperture is ready for use instantly by pushing the appropriate barrel into position. The external appearance of the optical system was not altered for ultraviolet recording, although different lenses are required together with the necessary filter. Although at the time when manufacture of the present recorders was begun it was expected that they would later have to be adapted to ultraviolet recording in the field, these recorders have been completed with the ultraviolet feature ready for use.

These optical systems, like all their prototypes, are equipped with a monitoring aperture allowing a second beam of light to be modulated by the same galvanom-

eter mirror that deflects the exposing beam of light. In this newest system this monitoring beam is not only projected upon a white card so as to be visible, but is magnified by a small projection lens so that the image may be viewed with still greater accuracy. An innovation arising from using the practically invisible ultraviolet light is to make use of the deep red component of the incandescent source for the viewing telescope. This component of the light is allowed to pass through the filter, and causes no exposure of the film because it is beyond the spectral cut-off of the emulsions used.

The dry magnetic galvanometer, described previously, is essentially unchanged. It has a large, untarnishable front-surface mirror. This galvanometer has been satisfactory not only because of its excellent frequency response, but because of its self-protection against overloading by saturation of its magnetic structure at double normal deflection. The resonance frequency is 9500 cps.

FREQUENCY CHARACTERISTICS

The frequency-response curves and directional characteristics of the microphones have been published previously, and are sufficiently uniform over the frequency range between 30 and 10,000 cps. to represent eminently satisfactory units. The response of all amplifier equipment is uniform within 0.2 db. between 30 and 10,000 cps., with the exception of the microphone amplifier which deviates from this characteristic only because of the film-transfer compensation introduced into it. The attenuation of the mixer proper is uniform over the same range. The two degress of low-frequency attenuation available are adjustable to particular circumstances, but are usually set to attenuate in a smooth curve starting at 500 cps. and reaching 9.0 and 13.0 db., respectively, at 100 cps. The high-frequency attenuator begins effectively to reduce the response at 5000 cps., and follows a smooth curve to an attenuation of 9.0 db. at 10,000 cps. The galvanometer responds uniformly over the same range within +2.0 and −1.0 db.

INSTALLATION

Although practice in the industry has favored the use of a monitoring booth with a loud speaker, many recordists prefer to do their mixing upon the set, in order to be able to study the action, note the microphone position, *etc.* It is believed that this is the ideal procedure, but that its adoption has been considerably delayed by the lack of a satisfactory high-quality head-set. With this deficiency overcome, and with the advent of the neon volume indicator, the only practical bars to mixing upon the set have been overcome and the present system has been specifically designed to this end without hindering in any way its use in a monitoring booth.

Using the recording system according to either method of mixing presents no installation problem; but the fact that either procedure may be required of a single installation has made the problem somewhat more difficult. In addition, it is sometimes necessary, particularly with mobile channels, to locate the microphones sufficiently far from the mixer to necessitate locating the microphone amplifiers quite remotely from the mixer also.

The problem was solved by designing universal distribution boxes for allowing the system to fulfill all these requirements by means of a change in the cable connections. The schematic arrangements are shown in Fig. 8.

RE-RECORDING

This recording system forms an ideal basis for a re-recording system, and may be used interchangeably for the purpose if only a limited amount of additional equipment is available. A well planned re-recording system should use a proper mixer and compensator. These units are composed of standard assemblies engineered to fulfill special customer requirements. Essentially, the mixer pads have

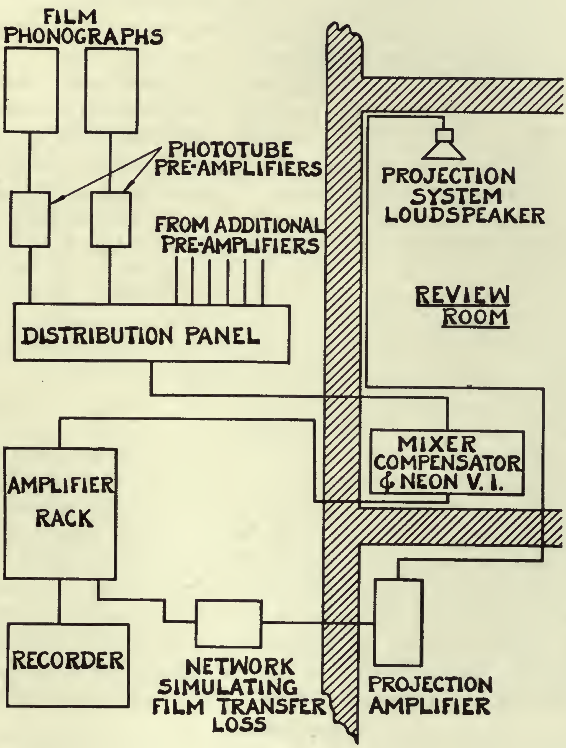

FIG. 8. Re-recording installation.

a greater range of attenuation than the recording type, and special low-, high-, and middle-frequency attenuators are supplied. These attenuators may be used as a "sick bay," for salvaging poor recordings, or they may be used scientifically to compensate for varying acoustical conditions and to make the necessary adjustments for differences in loudness between the original sound and the reproduced version. Any number of mixer positions are available in units of four, and two additional mixer positions are available for plugging in tandem with any of the other pads in order to permit extending the attenuation range or to predetermine instantaneous changes in level such as those caused by closing a door.

An ideal re-recording layout is shown in Fig. 8. The film phonographs may be either the magnetically driven type, very similar to the recorder described in this paper, or rotary stabilizer sound-heads with film feed mechanisms replacing the usual projectors. In some instances the projector may be mounted upon the sound head, if it is necessary to re-record and project simultaneously from a composite print. In any arrangement the phonograph may be required to scan symmetrical or push-pull sound-tracks. The change from one type to the other may be accomplished by operating a key in the phototube circuit.

The film-transfer loss equalization is accomplished in the pre-amplifiers exactly as described for the microphone amplifiers.

With the exception of the re-recording mixer and compensator, the remainder of the system may be the same as a recording system arranged for direct recording, However, a very decided advantage may be gained by using an acoustically corrected review room for monitoring. If a projection system is available, such a review room furnishes an excellent means of monitoring re-recording and even direct scoring. Fig. 8 shows that the usual monitoring speaker has been replaced by the review room amplifier and loud speaker system. A network is introduced to simulate film-transfer loss, including the loss caused by the slit in the reproducer usually associated with the review room amplifier. With this arrangement re-recording monitoring may be accomplished under conditions very closely approximating those existing when the resulting print is returned from the processing laboratory and is reproduced in the review room.

This eliminates monitoring problems caused by variations in acoustics and levels between monitoring and reviewing rooms.

The recordist possessing a review room having a high-quality recorder connected as outlined above will have a means of checking carefully all work. By attending the theaters, he can eventually train himself to interpret the performance in the review room in terms of the results in the theaters, which is not a difficult task under these conditions because the only variable for which the recordist must compensate mentally is the difference between review room and theater performance.

The members of the RCA engineering department responsible for the design and coördination of this recording system are Messrs. Anderson, Collins, Dimmick, Gunby, Klinedinst, Pulley, Read, Reiskind, Willman, and Whitcomb. The work was performed under the inspiration and guidance of Mr. M. C. Batsel.

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A NEW ROTARY STABILIZER SOUND HEAD*

F. J. LOOMIS AND E. W. REYNOLDS**

About three and a half years ago, the first rotary stabilizer sound heads were introduced to the trade. Originally designed as *de luxe* equipment, and intended primarily for large theaters, the sound heads gave such consistently excellent performance that their use became widespread.

The rotary stabilizer principle of sound reproduction has been previously described in the JOURNAL.[1] It is sufficient to repeat that this device eliminates from sound reproduction the two major causes of sound distortion, sprocket-tooth ripple, and sprocket revolution "wow." It maintains indefinitely its original high standard of reproduction, with no adjustment, little attention, and practically no deterioration from wear. The sound quality may actually improve with use of the machine.

Since the original rotary stabilizer was placed in operation, advances in recording and reproducing systems, and an appreciation of some of the not so obvious points of the rotary stabilizer have caused us to design a new sound head retaining all the advantages of the previous model and introducing some additional features.

The backbone of any sound head is its main frame. This one is a solid iron casting, made in rigid box form, the four sides integral with the center web. Upon the top are provided keyhole mounting slots for the projector, the advantages of which will be described later. At the rear, provision is made for the pedestal arm, and at the front end are the motor bracket bosses, and on the bottom are the magazine bosses. The central web carries the two sprocket-shaft bearing holes, the pad rollers, strippers, and three bosses for mounting the sound bracket casting.

Upon the conventional solid foundation of the main frame are built the parts of the sound head in a manner far from conventional. In the construction of these parts there is a definite cleavage between two divisions, the sound reproducing division and the power drive unit.

The power drive begins with the motor, which is ordinarily a conventional split-phase induction motor rated at $^1/_4$ hp., but capable of delivering $^1/_3$ hp. Such a motor provides great excess of reserve power to care for poor voltage

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* Presented at the Spring, 1936, Meeting at Chicago, Ill.

** RCA Manufacturing Co., Camden, N. J.

regulation, sticky projectors, and cold starting conditions. As an indication of the reserve power of the motor, the speed when driving the mechanism is closer to the no-load than to the rated-load speed. The economics of what would ordinarily be called an oversize motor may be questioned, but our experience has been that the oversize is amply justified by excellent speed regulation, high available starting torque, and long life. The motor will continue to drive the machine at 90 feet per minute ± 0.5 per cent under very adverse conditions of load and voltage.

For starting regulation, an adjustable resistor is provided, connected in series with the starting winding and mounted inside a box at the side of the motor, where the motor starting switch is also mounted.

To eliminate the inherent unbalanced torque vibration present in a single-

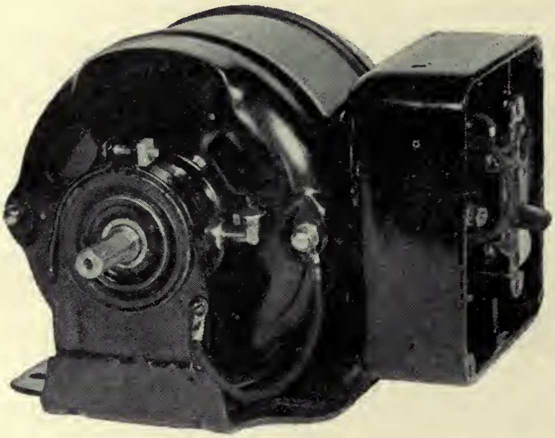

FIG. 1. End view of motor, showing rubber hub mounting.

phase motor, the motor is hub-cradled in two oil-resisting rubber rings, as shown in Fig. 1. This type of mounting is rapidly finding favor with motor manufacturers, and is the most successful ever developed for reducing vibration and noise. A test of the mounting compared with the conventional solid type is strikingly in favor of the hub rubber mount.

The motor is mounted upon a cast-iron bracket bolted to the main frame and connected to the worm shaft by a flexible coupling, as shown in Fig. 2. The coupling was selected from a large number available, as allowing the maximum misalignment with a minimum of vibration.

The driving-gear train is shown in Fig. 2, and consists of a multiple-toothed worm running between two identical gears, one of which is on the lower hold-back, the other on the constant-speed shaft. By changing the gear mechanism, any desired speed ratio can be attained for different drive-motor frequencies. The worm and the two sprocket-shafts are mounted on oversized ball-bearings, and the entire assembly is lubricated by the action of the lower gear running in the oil, which is maintained at a constant level in the case. This action throws oil over

the entire assembly. To eliminate leakage of oil at the various bearing holes, oil flingers and large return passages are provided at the various exits. All three shafts, including the worm, which is integral with its shaft, are made of heat-treated chrome nickel steel, and the gears are of the highest quality cast gear bronze. All worms, shafts, and gears are of ample proportions, assuring continuous service.

The gear box housing is screwed securely to the center web of the main frame. A large cast-iron gear is mounted upon the outer end of the constant-speed sprocket shaft and drives up to the projector drive train. A unique method of holding the two sprocket-shaft assemblies together is provided by a coil spring, cup washer, and *C*-washer. This method permits quick and easy assembly and disassembly, and allows for truer running shafts than the conventional clamping nut, taper-pin, or set-screw methods of mounting.

On the operating side, shown in Fig. 3, the conventional two sprockets, constant-

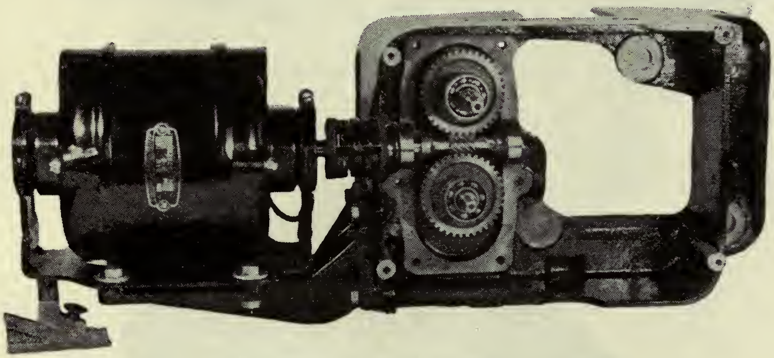

FIG. 2. Motor coupling and sprocket drive gears.

speed and hold-back, are provided, along with strippers and pad-rolls. The strippers are die castings, and are readily adjustable for sprocket clearance. Pad-roll arms are the same as previously used, and provide a very wide opening, together with a firmly locked operating position and an easily adjustable sprocket clearance. Due to the action of the rotary stabilizer, the constant-speed sprocket has an indefinitely long life.

Having described the complete system of power drive, we arrive at a definite line of demarcation between power drive and the sound reproducing parts. In previous designs, it has been customary to cushion mechanically each separate sound part that might display a tendency to be microphonic. For instance, exciter lamps were frequently cushioned, as were photocells, audio transformers, and head amplifiers. The net result was frequently unsatisfactory, because each part had a small mass and had to be rather stiffly mounted to remain in mechanical alignment.

In this sound head all the sound parts, beginning with the exciter lamp and progressing through the optical system, stabilizer and drum, collector lens, photocell and audio transformer, are mounted upon one solid casting, which is itself

vibration-damped from the remainder of the sound head. This design is superior to the old method of filtering vibrations; first, because it holds all the sound parts in rigid alignment so that they can not vibrate with respect to each other; and second, the entire assembly has such large mass that even though compara-

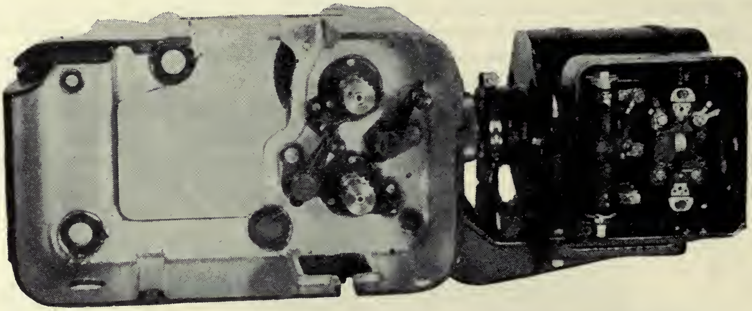

FIG. 3. Operating side of Fig. 2.

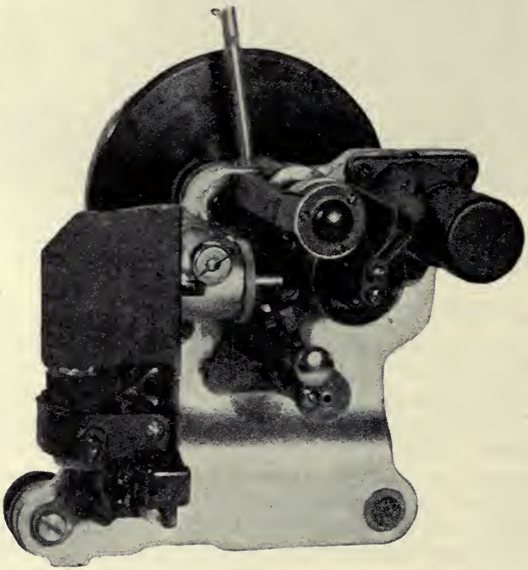

FIG. 4. View of sound parts, from operating side.

tively stiff mounting cushions are used, the filtering action of the combination is very effective.

A view of the operating side of the sound parts mounted on their castings is shown in Fig. 4. The exciter lamp socket is mounted upon two horizontal pins, and is instantly replaceable in case of lamp burnout. The socket has a micrometer

adjustment for vertically positioning the lamp filament and can be locked in place. A heat-insulating handle is provided so that the sockets can be easily and safely exchanged by the operator.

The optical system fits into a cylindrical mount bored in the sound bracket casting, and has a micrometer focusing adjustment and a locking clamp. The system is hermetically sealed to exclude oil vapor, and the front lens is guarded against accidental contact, although it can be easily cleaned. The angle of the image is fixed by precision machining processes.

The stabilizer drum and shaft is made from a one-piece heat-treated chrome nickel steel forging, precision machined with great exactness. It is mounted on accurate free-running ball-bearings suitably protected against dirt. It is practically a duplicate of the earlier drum and shaft except that it has a greater spread between the bearings.

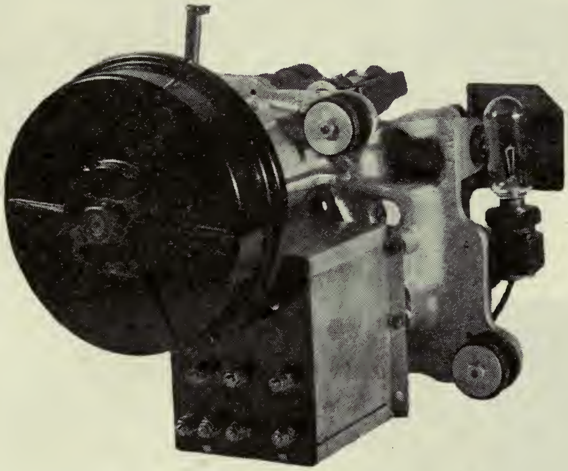

FIG. 5. Rear view of sound parts assembly.

The collector lens and photocell bracket are the same as previously used. The light-image is refracted outwardly and upwardly by the lens and is condensed at the same time so as to form a suitable spot upon the photocell target.

The lateral guide and pressure-roller also follow the same general design as previously. A hard felt pressure-roller holds the film at the entering point against the stabilizer drum, while the two flanges, one in fixed position, and one spring-controlled, accurately guide the film laterally. The entire assembly of flanges and roller is mounted upon a shaft carried by two ball-bearings. The assembly is held against the drum by light spring pressure in the knee joint of the lower arm, and is easily swung back from the drum for threading. Lateral adjustment of the film is attained by moving the entire assembly along a stud mounted in the sound bracket.

The rear view of the sound parts casting, Fig. 5, shows the method of cushion-mounting upon the main frame. One cushion assembly consists of a stud, two

soft molded cushions, and a suitable nut, washer, and lockwasher. The cushions fit into large holes in the main frame, and prevent any possible metal-to-metal vibration-transmitting contact. The cushions are a synthetic rubber compound, extremely resistant to deterioration from both oil and age.

The audio transformer is mounted upon the casting adjacent to the photocell socket, and is connected by asbestos-insulated leads so that deterioration of the

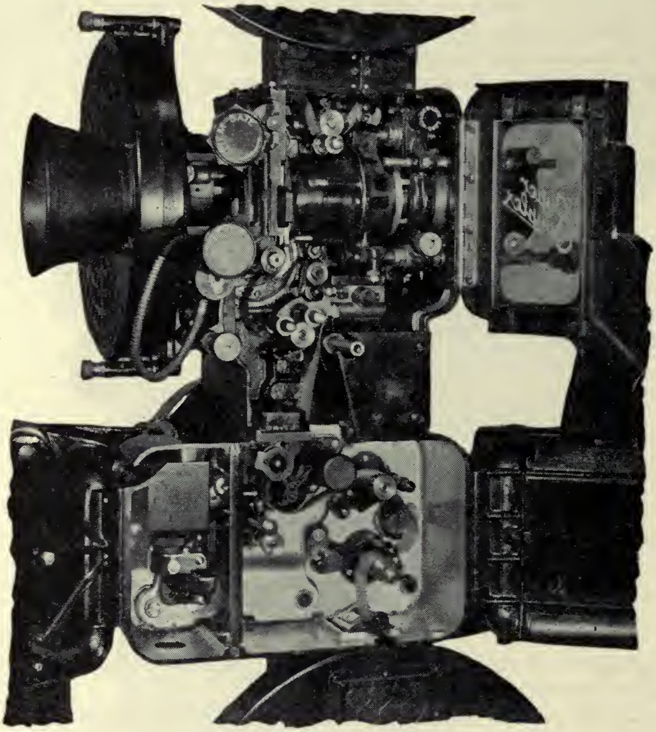

FIG. 6. Assembled projector and sound head.

leads by oil is not a factor. The transformer is permanently potted in compound so that oil and moisture can not injure it. It is well shielded electrically.

The rotary stabilizer itself departs from the previous design in mechanical details only, the principle of action and general dimensions remaining the same. Service records carefully kept over three and a half years have shown that the stabilizer may be permanently sealed, so that the new one has its cover permanently spun into place. This construction eliminates the unsightly and expensive method of screwing the cover in place, and is superior to the old one because it provides a casing that is permanently oil-tight and gives a better mass ratio.

It is interesting to note that, except for the mounting cushions, the only me-

chanical connection between the sound parts and the power drive parts are the two loose loops of film on either side of the stabilizer drum. The conventional gate type of machine requires a tight stretch of film between the gate and the constant-speed sprocket, so that the gate machine does not lend itself to vibration-insulating the sound parts as well as does the stabilizer machine.

The interior of the operating side is finished in silver gray to afford better visibility. The doors are deep, heavy die-castings. The door covering the operating compartment is provided with a large glass window, as well as a stop to prevent it from opening too wide, and a safety stud to assure that the operator closes the guide and pressure-roller on the drum after threading the machine.

Mounting or removing the projector is made an easy task, either at the time of installation or in case of trouble, by providing large keyhole-shaped slots in the top of the sound head. The two mounting-bolts are threaded into the bottom of the projector before the projector is placed upon the sound head. The bolt heads can then be inserted through the enlarged portions of the keyholes, the projector moved forward to its proper position, and the bolts tightened. To remove the projector, it is necessary only to loosen the bolts, move the projector back, and detach it. Slotting the sound head top eliminates also the use of shims between projector and sound head. Proper gear mesh can be effected by moving the projector forward until the drive-gear meshes correctly with the sound head gear.

An additional convenience is included in the design of the pedestal arm, which has two open-end slots in the top of the vertical mounting surface. By inserting the two upper screws into the sound head, it can be hooked instantly to the arm. All screws can then be quickly and easily tightened. In earlier models, it was necessary to hold the heavy sound head in line while entering the mounting bolts, which usually required two men.

The complete equipment is shown in Fig. 6.

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A SOUND-PICTURE REPRODUCING SYSTEM FOR SMALL THEATERS*

G. PULLER**

The Western Electric Sound Picture Reproducing System described in this paper was developed by Bell Telephone Laboratories, primarily to meet a demand for a system capable of high-quality reproduction from film in motion picture theaters of small seating capacity. The system was introduced by Electrical Research Products, Inc., during the early part of this year. All the essentials of a good sound-film reproducing system have been incorporated in the new simplified system which is especially designed to fit the needs of small theaters.

A complete system consists of two reproducing sets; a control unit, which provides switching means for the power and voice circuits and the exciter lamps; a system amplifier, power supply unit, and monitoring loud speaker, all housed in a single cabinet; and the stage loud speakers. By means of the control cabinet, either photoelectric cell may be connected to the system amplifier input, the associated exciter lamp current being switched simultaneously to its normal operating value. Both exciter lamps are connected in series, the exciter lamp current of the stand-by reproducer being reduced to about one-half its normal operating value. The equipment is operated entirely from a 105- to 125-volt, 50- or 60-cycle power supply.

The reproducing set consists of a standard Simplex picture projecting equipment employing any of the various Simplex types of projector mechanism, the lower film magazine being supported by either an *R* or an *L* type of pedestal. The sound reproducer reproduces the sound-track recordings of standard 35-mm. variable-width or variable-density sound-film into an electric current suitable for amplification. It is mounted between the usual Simplex pedestal arm and the lower film magazine, as illustrated in Fig. 1, and consists of a frame casting with a single compartment housing the film speed control mechanism which in this reproducer consists of an inertia-controlled scanning drum, or kinetic scanner, mounted on precision ball bearings to reduce friction to a minimum. Extra precautions have been taken to seal the ball bearings effectively against the entrance of dust, which would interfere with the smooth rotation of the scanning drum and introduce disturbances in the reproduced sound. The construction is such that the initial lubrication should last for an indefinite period. The kinetic scanner and its associated parts are manufactured to the highest degree of precision, and the final assembly is accurately balanced in order to assure uniform travel of the film past the scanning point and to prevent the film from weaving

* Presented (by title) at the Spring, 1936, Meeting at Chicago, Ill.

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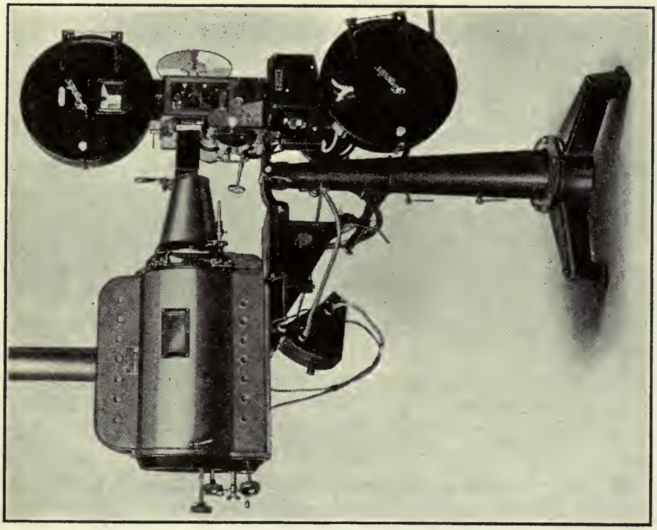


FIG. 1. Sound-picture reproducing system for small theaters, showing the reproducer mounted between the Simplex pedestal arm and the lower film magazine.

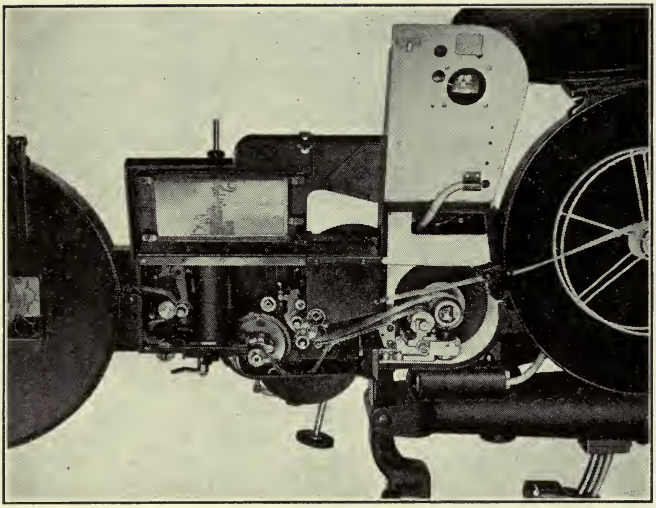


FIG. 2. The path of the film through the projector magazine and the sound reproducer.

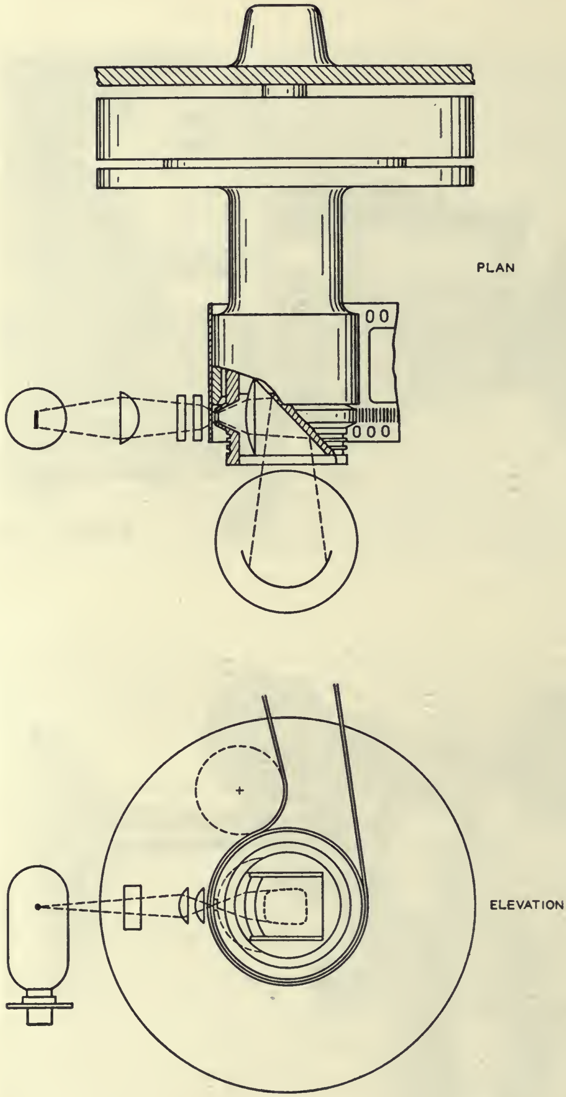


FIG. 3. A totally reflecting prism having one convex surface, located within the scanning drum, deflects and focuses the light-rays at right angles into the photoelectric cell after passing through the sound-track. The aperture in the prism holder limits the length of the scanning line, and is shielded to exclude stray light.

in and out of its proper focal plane. Constant speed of the scanning drum is maintained by means of the specially designed double flywheel of the kinetic scanner. One flywheel is integral with the scanning drum, which effectively prevents high-frequency oscillations of the film; the other is free-floating, and is coupled to the first by means of a mechanical filter which effectively suppresses slow oscillations. The kinetic scanner is so stabilized that a sudden change in the film speed or a disturbance in the film loop, such as the passage of a film splice, has no appreciable effect upon its uniformity of rotation. During the acceleration period of the scanning drum the two flywheels are coupled together by means of a centrifugal clutch.

As shown in Fig. 2, the film is threaded into the projector mechanism in the usual manner, up to the intermittent sprocket, from which it passes directly through a film chute into the sound reproducer. Here it is guided by a pivoted guide roller onto the scanning drum of the kinetic scanner, around which the film is wrapped. From this point it passes up to the lower feed sprocket in the projector mechanism and thence down to the lower film magazine. A clear path is presented for easily threading the film and for accessibility of the parts of the mechanism inside the sound reproducer.

The extremely low friction of the kinetic scanner allows the film wrapped around the scanning drum to rotate the scanner without being subjected to appreciable tension. This results in the formation of an elastic film loop between the scanning drum and the feed sprocket, introducing a compliance between the feed sprocket and the scanning drum and preventing the sprocket tooth impulses from being transmitted to the scanning point. The film chute can be readily dismantled for cleaning. Film scratching and abuse are eliminated by the use of highly polished film guides. The pivoted guide roller is supported between bronze bearings lubricated through covered oil-cups, and provides an adjustable means for guiding the film edgewise around the scanning drum and retaining the sound-track of the film in its proper path with respect to the center of the light-beam. The flanges that guide the film edgewise are chromium-plated to resist wear. The guide roller adjustment is accomplished by a slotted knob accessible through an opening in the closed door. No film sprocket or sprocket drive mechanisms are employed in the sound reproducer, thus resulting in a simple construction. The location of the lower film magazine is such that the usual projection angles are readily attained.

The exciter lamp constituting the light-source is mounted in a separate holder external to the sound reproducer. To eliminate adjustments and to facilitate replacements in case of lamp failure, a new type of lamp provided with a prefocus skirt on its base is employed.

The lens tube assembly is hermetically sealed and is exceptionally efficient in terms of light output. It images the incandescent filament of the high-intensity exciter lamp as a concentrated line of light directly upon the sound-track of the film by means of cylindrical lenses without the use of a mechanical slit. It operates in an over-all distance of 75 millimeters between lamp filament and film plane. The lens tube assembly may be adjusted when the compartment door is closed by removing a latch plate, thus exposing an opening through which the focusing adjustment at the back of the lens tube may be made and a screw and lock-nut for adjusting the light-beam azimuth. A totally reflecting prism having

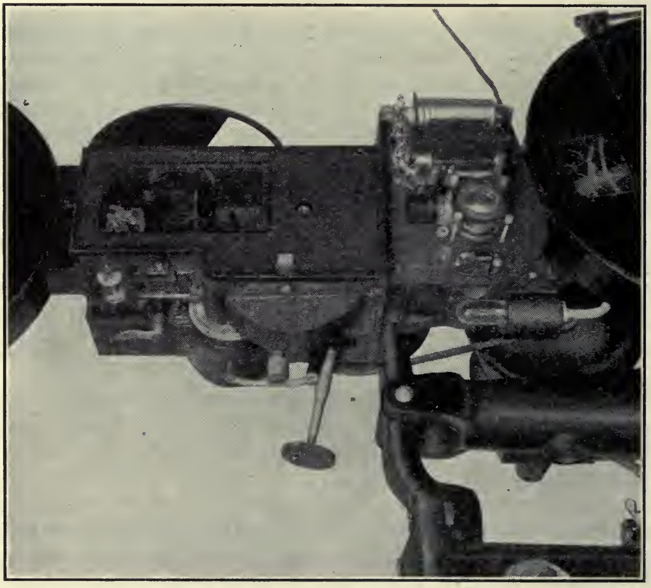


FIG. 4. The photocell and associated transformer and condenser are mounted upon the door of the film compartment, shielded against electrical disturbances by a sheet metal cover.

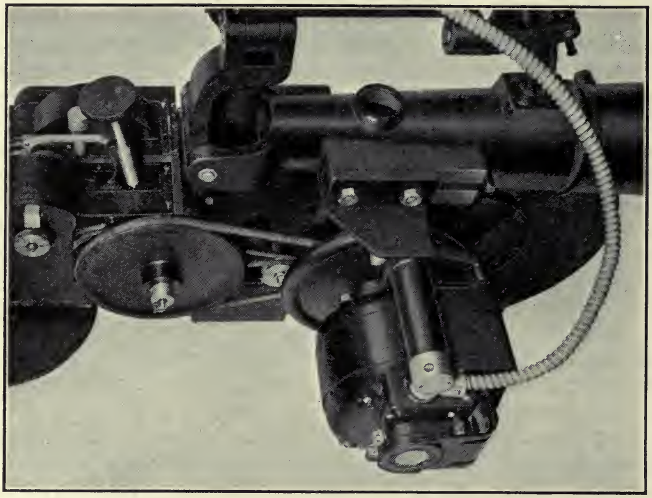


FIG. 5. The endless belt drive of the Simplex projector mechanism.

one convex surface is located within the scanning drum to deflect and focus the light-rays after passing through the sound-track, out at right angles into the photoelectric cell, as shown in Fig. 3. The prism is mounted in a holder which can be removed readily for inspection and cleaning without disturbing its adjustment. The prism holder incorporates an aperture which is introduced immediately behind the point at which the film is scanned to limit the length of the effective scanning line. The aperture opening is such that only the light passing through the 0.083-inch-long aperture reaches the photoelectric cell by way of the prism, the aperture being shielded to prevent stray light from entering and affecting the

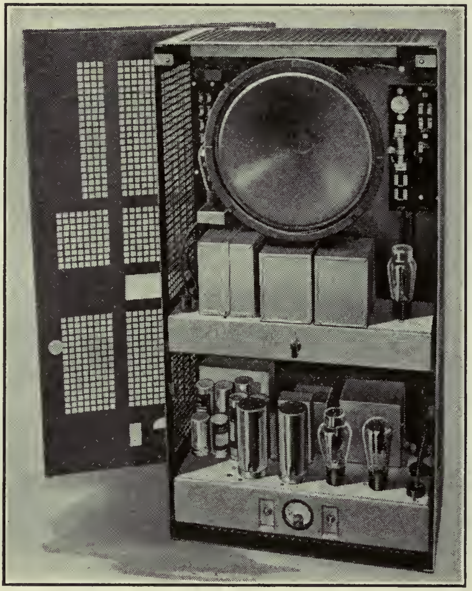


FIG. 6. The cabinet containing the amplifier, rectifier, monitoring loud speaker, and associated equipment.

sound reproduction. Precaution have been taken to assure that the mask aperture is not easily obstructed by dirt or film particles adhering to its edges.

Although the system was primarily designed for use with Simplex projectors, a similar sound head is available for Powers projectors.

The Western Electric photoelectric cell with its associated transformer and condenser are mounted upon the door of the film compartment, as shown in Fig. 4. The entire assembly is protected by a sheet metal cover which acts also as a shield against stray electrical disturbances.

The photoelectric cell is mounted in a cushion support to minimize vibration and resultant microphonic disturbances. The associated photoelectric cell transformer is likewise cushion-mounted, in order to eliminate microphonic

disturbances. A flexible armored cable is employed to bring the photoelectric cell circuit from the door to the terminal compartment at the front end of the sound reproducer. From here the sound circuit extends through the main amplifier and thence to the stage and monitor loud speakers. To facilitate ready inspection and to avoid damage during shipment, the kinetic scanner is arranged for easy removal. Since its removal also necessitates the removal of the optical assembly, this part is located in the sound reproducer frame by removable dowel pins, thus assuring the correct replacement of the optical assembly after having been removed.

As shown in Fig. 5 the Simplex projector mechanism is driven by means of a round endless belt. The motor used to drive the equipment is a $^1/_6$-hp. single-

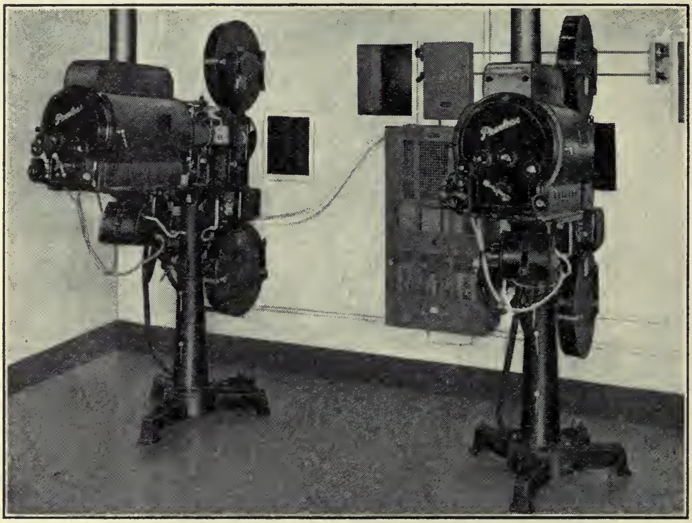


FIG. 7. A typical projection room installation.

phase induction motor having a split-phase starting winding. A combination flywheel and handwheel is attached to the driving motor to prevent the projector mechanism from starting too rapidly when the current is turned on, which might result in film damage, and to facilitate turning the machine over by hand during the film-threading operation. The pulley which is integral with this handwheel is arranged to propel the film at a speed of 90 feet per minute. As usual with this type of motor the speed regulation depends upon the frequency of the power supply. The motor is suspended in a rubber-cushioned frame in order to reduce vibration to a minimum. This, in turn, is mounted upon a pivoted bracket secured to the projector pedestal. In order to adjust and maintain the driving-belt tension to the minimum required to drive the projector mechanism reliably, the motor weight supplying the tension is partly balanced by means of an adjustable torsion spring.

The driven pulley is equipped with a gear which meshes with the projector gearing. This pulley and gear rotate on a stationary shaft supported from the projector. Lubrication is provided through an oil-cup conveniently located. The take-up drive of the lower film magazine is connected by a belt directly to the projector mechanism in the conventional manner, an adjustable tension pulley being provided for maintaining the proper tension to the belt driving the lower take-up reel.

The associated amplifier set is housed in a perforated steel cabinet intended for mounting upon a wall and suitably ventilated. A removable metal front is provided so as to simplify maintenance. In Fig. 6 is shown the cabinet in which are mounted the amplifier, rectifier, monitoring loud speaker, and associated equipment. A three-stage resistance-coupled amplifier is used, employing two suppressor-grid pentodes in the preliminary or voltage amplification stages, one high-transconductance triode in the output stage, and one full-wave rectifier tube. The amplifier also furnishes polarizing potential for the photoelectric cells and field energy for the monitoring loud speaker in the amplifier set. It has

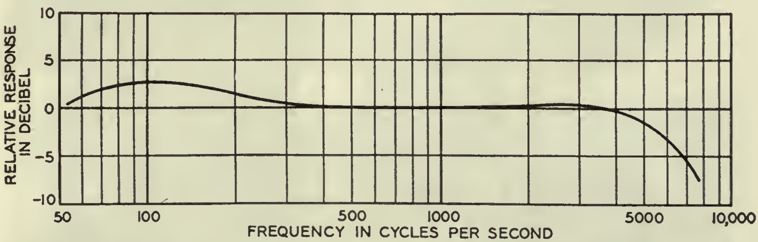


FIG. 8. The relative transmission-frequency characteristic of the system, from modulated light into the photocell to the amplifier, in terms of output load.

an undistorted power output of 8 watts. A separate power supply furnishes rectified and filtered current for the fields of the loud speakers on the stage and for the photoelectric cell exciter lamps.

A control cabinet intended for mounting upon the front wall of the projection room between the two projectors is used for connecting the output of either of the two reproducer sets to the amplifier, for volume control, for switching between exciter lamps, and for exciter lamp equalization. The extension controls with which this cabinet is furnished makes it convenient for operation from either of two projectors. A typical projection room installation is illustrated in Fig. 7. The potentiometer associated with the control cabinet permits adjustment of the input level to the amplifier in 2-db. steps. From the amplifier the sound circuits are conducted to the stage loud speakers, the number and size of which depend upon the installation requirements.

In Fig. 8 is shown the relative transmission-frequency characteristic of the system, from modulated light into the photocell to voltage out of the amplifier, in output load. The new system is compact, easy to operate, and as simple and economical in construction as is consistent with the maintenance of high-quality sound reproduction.

A NEW 16-MM. SOUND-FILM PROJECTOR*

C. R. HANNA, K. A. OPLINGER, W. O. OSBON, AND S. SENTIPAL**

The increased portability and the improved performance of 16-mm. sound-film projectors developed during the past few years has been remarkable. In 1929 experimental apparatus of reasonably satisfactory performance weighed more than one hundred pounds, which was thought at that time to be quite small.[1]

This paper describes new projection equipment that is believed to be smaller and lighter than any previously designed. Despite its simplicity and portability, every feature contributing to performance has been included.

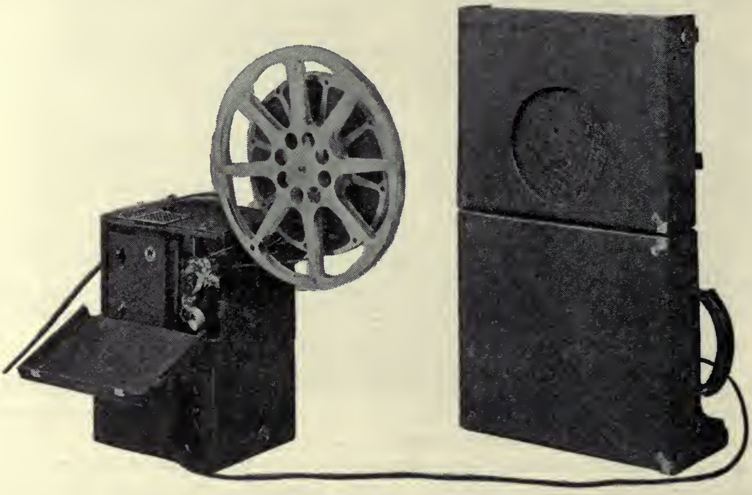


FIG. 1. Complete projection equipment.

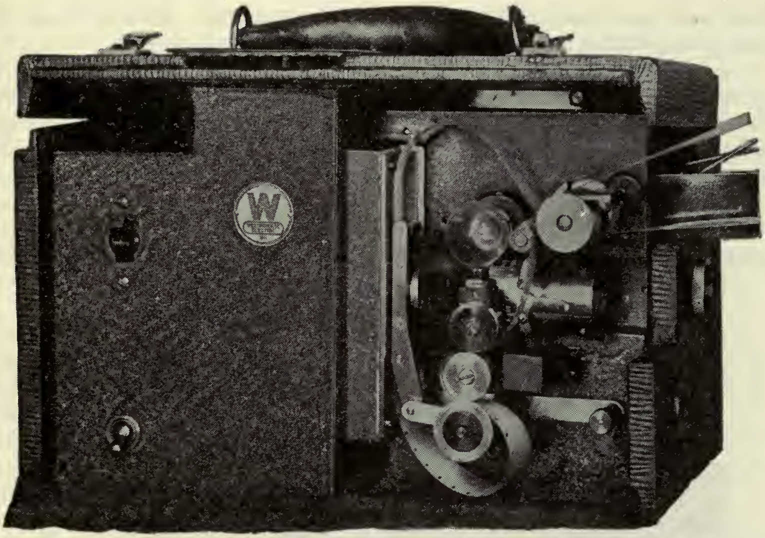
General Design Features.—The projector uses a 750-watt lamp and is equipped with a 12-watt amplifier, thereby providing sufficient light and volume for satisfactory operation in auditoriums. It will accommodate 1600-ft. reels affording a full forty-five minute showing with a single threading.

The complete equipment is built into two small cases, shown opened for operation in Fig. 1. A good idea of the size of the cases may be obtained by comparing them with the 1600-ft. reel, which is approximately fourteen inches in diameter.

The case containing the projector and amplifier is divided near the center, making two distinct units. This construction makes it possible to use the projector

* Received June 2, 1936.

** Westinghouse Electric Mfg. Co., East Pittsburgh, Pa.



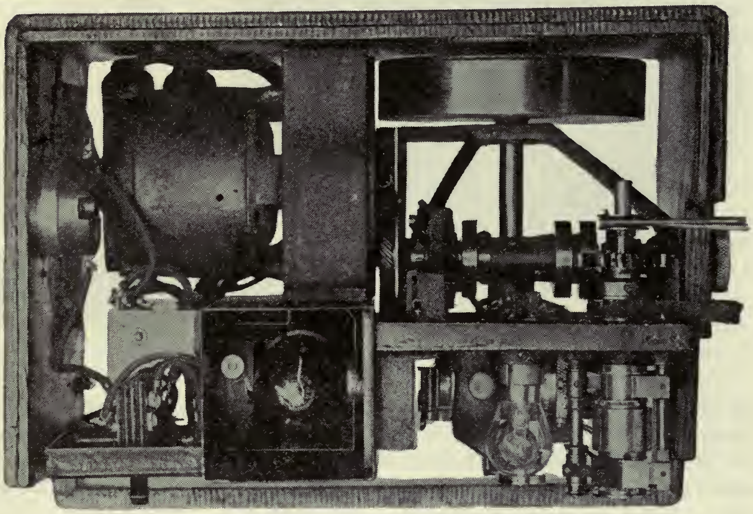


FIG. 2. (*Upper*) Front view of projector.
FIG. 3. (*Lower*) Top view of projector.

by itself for showing silent pictures, and adds to the flexibility of the equipment by making the amplifier a separate unit. The two units may be carried together quite easily, since their combined weight is only 34 pounds.

The loud speaker case is hinged at one side so that the speaker is raised from the floor when the case is opened. When closed, the case is approximately the same height as the projector-amplifier case. Space is provided to accommodate addi-

tional reels, spare tubes, cable, and the reel arm bracket. The weight of the speaker case without films is 17 pounds.

In operation both reels are positioned on the same bracket, as shown in Fig. 1. The full reel is placed at the rear, and after the film passes through the projector it is taken up by the front reel. To rewind, the full reel in the front is removed from the bracket and placed upon a support which may be attached to the lid of the case. The film is then wound back upon the empty reel by a hand-operated geared rewind which is part of the bracket.

Projector Details.—A front view of the projector is shown in Fig. 2, which shows clearly the simple method of threading the film. The sound and picture optical

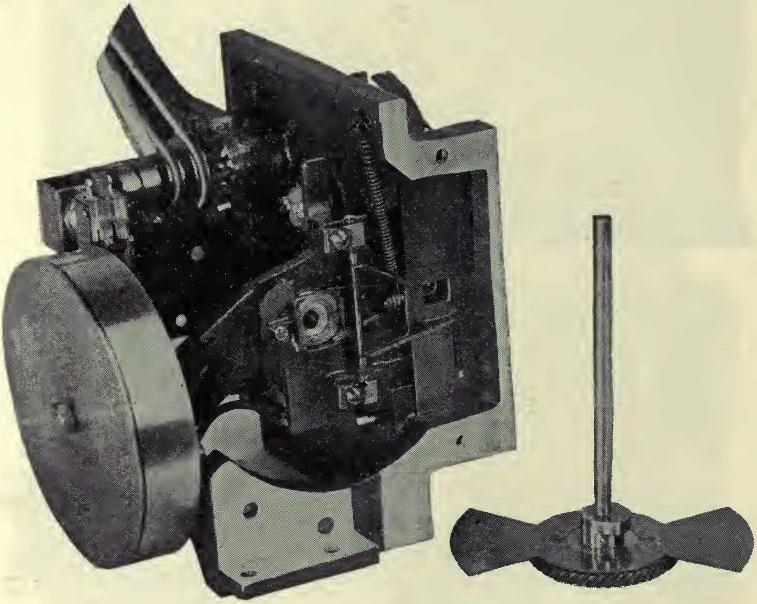


FIG. 4. Intermittent movement.

systems are close together, the sound optical system being displaced toward the operator by skewing the film as it comes from the picture gate. This construction gives the projector much of its simplicity and compactness. Further simplicity was achieved by mounting the feed and hold-back sprockets upon the same shaft. Only four grears are required in the projector.

The picture gate is conveniently opened for threading by means of the lever and pin shown at the lower right of Fig. 2. After the film leaves the picture gate, its movement is filtered by means of a rotary viscous damper,[2] which is pulled by the film. The damper runs so freely that the film pulling it forms a slight loop, which absorbs the irregularities in the film movement introduced at the sprocket. To provide traction between the film and the rotary damper, the film is wrapped about 180 degrees around a small hub upon the damper shaft and is held in contact with this hub by means of a pressure roller. The pressure roller is made self-

aligning with the axis of the damper shaft by mounting it upon a centrally placed ball bearing. Lateral adjustment of the pressure roller permits aligning the sound-track with its optical system.

The sound optical system is mounted with its axis vertical, and is composed of cylindrical lenses that image the filament of the sound lamp upon the sound-track, thus avoiding the use of slits. After the light passes through the edge of the film it is transmitted to the amplifier in the lower case by means of a system of mirrors and lenses. Vertical and rotational adjustments of the sound optical system are provided to permit focusing and orienting the light image upon the film. These are really factory adjustments, as they are rarely changed. Lamps are interchangeable without requiring adjustment. The sound lamp serves also as a threading lamp. Its voltage is automatically reduced when the projector is stopped.

Fig. 3, a top view of the projector, shows the location of the motor, blower, and lamp housing. The blower fan is mounted directly upon the motor shaft with its outlet into the side of the lamp housing. Air may enter the fan from both sides. The lamp house has double walls arranged so that part of the forced ventilation passes between the inner and the outer shells to keep the front panel cool. The amplifier is cooled by drawing part of the inlet air through an opening in the lower compartment.

The speed of the motor is controlled by an electric centrifugal governor, which may be seen on the shutter shaft in Fig. 3. This governor has two independent sets of contacts which provide fixed speeds for showing sound or silent pictures. The desired speed is selected by a switch upon the front panel.

Fig. 4 shows the back of the picture gate and parts of the intermittent movement. To reduce the weight of the reciprocating parts to a minimum, the follower and claw are fabricated from sheet steel, with sufficient ribbing to afford the requisite stiffness. The follower has but two solid working sides; one for vertical movements of the claw and the other for engaging the claw with the film. A coil spring is used to hold the follower against the cam for vertical movements of the claw. This spring is designed to exert a force that is greater than that due to the friction and inertia of the moving parts, and it automatically compensates for the gradual wear of the contacting surfaces of the cam and follower. Another spring, in the form of a cantilever, is used on the follower for the "in and out" movements of the claw. Movements of the follower are transmitted to the claw by means of a small tube, which fits over a hardened steel ball fastened to the claw. The claw has its own slide rod bearing, which fixes the vertical travel of the claw parallel to the travel of the film. Engagement of the claw with the film is accomplished by placing the driving tube at a slight angle in the horizontal plane so that movement of the follower to the left or the right will result in an in or out movement of the claw.

The cam and follower are designed to "pull down" in 51 degrees which is less than $^1/_7$th the picture period. This movement is very rapid for a cam that rotates only at picture frequency, and is on a par with that of existing machines having double-speed cams. This lower speed is very desirable from the standpoint of quietness. The shutter blades have an angle of 60 degrees, so that the light is cut off during the entire interval of film movement.

The cam and shutter float on their drive shaft, and are coupled to it by means of a flexible spring. In combination with the inertia of the shutter, this spring

prevents pulsations of the intermittent from passing back into the gears, where they would cause noise. This filtering, along with the light construction of intermittent parts and provisions to prevent lost motion, results in very quiet operation of the projector. Further reduction of noise is accomplished by mounting the projector upon rubber supports in the carrying case, so that the projector noise is not objectionable even when the equipment is operated in a small room with a low level of sound output.

The Amplifier.—The amplifier is capable of delivering 12 watts of undistorted power, which is sufficient to fill a small auditorium. As is apparent in Fig. 5, the

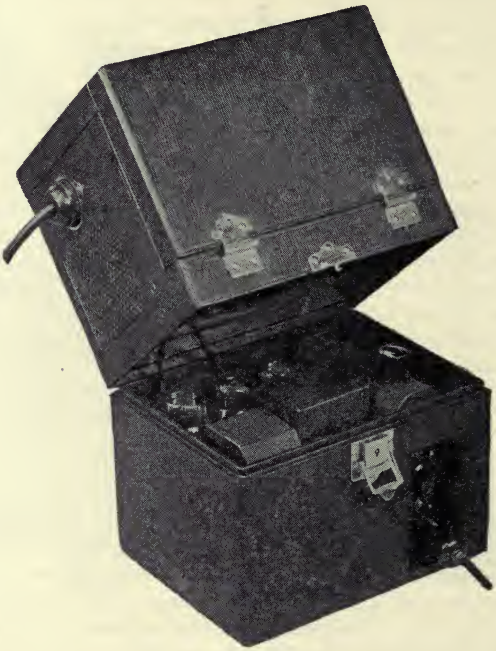


FIG. 5. The amplifier.

amplifier is unusually small and compact for a unit of such capacity. The overall dimensions exclusive of the case are $8^3/_4 \times 6^3/_4 \times 6$ inches, and the weight is only 15 pounds.

The metal cover at the right encloses the phototube and the first two stages, which are resistance-coupled. The second stage is transformer-coupled to the power stage, which consists of type *2A3* tubes in push-pull. The tube at the left is a type *5Z3* rectifier.

All controls are located in the recess at the front of the amplifier case. Control of volume is effected by varying the grid-bias of the first tube. A tone control is provided to compensate for the over-emphasis of low tones by reverberant rooms.

Provision is made for connecting a microphone to the amplifier input so that the operator may make announcements to the audience.

The use of a special low-current sound exciter lamp makes it feasible to supply this lamp with rectified and filtered current from the amplifier power supply. Thus a non-pulsating light-source results without the use of bulky and expensive auxiliaries.

Conclusion.—No quality feature has been omitted in the design of this projection equipment. High-power illumination and high-quality sound of great volume have been obtained with equipment of smaller size and weight than any heretofore designed; more important, these features, plus extreme quietness, have been achieved in a machine that is very rugged and simple.

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THE MAGAZINE CINÉ-KODAK*

O. WITTEL**

The desirability of magazine loading for sub-standard motion picture cameras has long been recognized. The principal advantages are two:

First, the avoidance of a threading operation, with consequent delays when lost time may mean a lost picture, plus the ever-present possibility of failure due to improper threading.

Second, the opportunity that magazines provide for changing quickly from one type of film to another without undue fog, even though the film has been exposed but part way through its length.

Several makes of motion picture camera have been marketed in which the broad principle of magazine loading is employed. Both the advantages inherent in this method of loading were not realized, however, before the advent of the Magazine Ciné-Kodak (Fig. 1).

The Magazine.—The magazine (Fig. 2) holds a net 50 feet of film. Its shell is drawn from 0.020-inch steel to withstand rough handling, and a baked black synthetic lacquer finish is applied to protect it against climatic conditions. The cover is held on with screws, but an adhesive tape acts as a seal against tampering and as an added barrier to the entrance of light. Inside the magazine are the

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* Presented at the Spring, 1936, Meeting at Chicago, Ill.

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driving sprocket, the chromium-plated gate where exposure takes place, a gear-driven take-up, and the necessary studs, guides, springs, *etc.*, to insure the proper running of the film, the maintenance of correct loops, and the recording of steady pictures at speeds varying from 8 to 64 frames per second.

The path of the film can best be understood by examining Fig. 2. It is evident

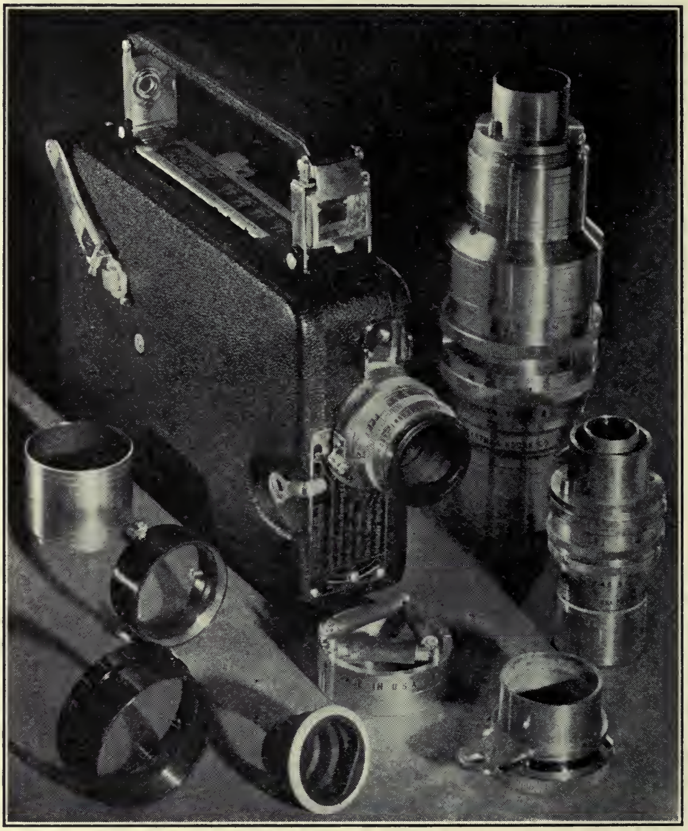

FIG. 1. The camera with an assortment of optical accessories.

that there is no departure from standard procedure as followed in the highest grade apparatus. Unlike other film magazines, there are loops, so that the intermittently moving section of the film is correctly separated from the continuously moving sections.

A feature that is particularly advantageous when the user shifts from one film to another is the sliding metal shutter that covers the picture aperture and the claw slot (Fig. 3), except when the magazine is in the camera and the safety lever

is set to *run.* This sliding shutter reduces the fog, and means, of course, that a magazine can be removed from the camera at any time, set aside, replaced later, and exposure completed.

Another feature is the film footage indicator, which is actuated by the varying diameter of the supply roll. Footage can be read through a window in the camera door and also directly upon the magazine if the latter is removed from the camera.

Even with all these features a magazine is, of course, only a film container until it is placed into the camera. The design of both units must be properly coördinated to give best results.

The Camera.—The mechanism is housed in a rectangularly shaped aluminum die-casting covered with leather. The camera measures $4^3/_4$ inches high $\times$ 1 $^3/_4$

FIG. 2. Interior of magazine.

thick $\times$ $6^1/_4$ long with the handle folded and exclusive of the lens. The weight is a little more than 3 pounds when loaded.

The mechanism is driven by two spring motors connected in parallel and wound by a folding crank. Eleven feet of film are exposed at one winding, with a positive stop at the end of the run. A train of gears, most of the elements of which are of steel alternating with phenolic material, drive the pull-down, shutter, governor, and magazine sprocket. At 64 frames per second the governor speed is 10,250 rpm. Such a high governor ratio has been found desirable to assure proper regulation over the wide range of camera speed.

The shutter problem in the thin camera was met, not by resorting to the oscillatory type, but by using a cone-shaped rotary shutter instead of the conventional disk. It gives an exposure of $^1/_{35}$ second. The pull-down claw is crank-driven, operating on the rachet principle. Loading is merely a matter of opening the hinged camera cover and inserting the magazine.

The camera is regularly equipped with a 1-inch $f/1.9$ lens, which is attached by a bayonet fitting, and for which other Ciné-Kodak lenses may be substituted.

FIG. 3. Camera and magazine. (Note film indicator on magazine.)

The extra lenses with suitable adapter, filters, lens caps, and hoods give this camera the complete versatility that 16-mm. workers expect.

A novel and very practical finder system gives correct fields for any of the lenses. The optical elements are supported in metal frames that serve also as carrying-handle brackets (Fig. 4). Instead of the ordinary front negative lens there are two elements, one stationary positive lens and one slidable negative element. When located at the forward end of the track, the finder covers the field of the 1-inch lens. As it is moved back the field narrows and the various longer focal

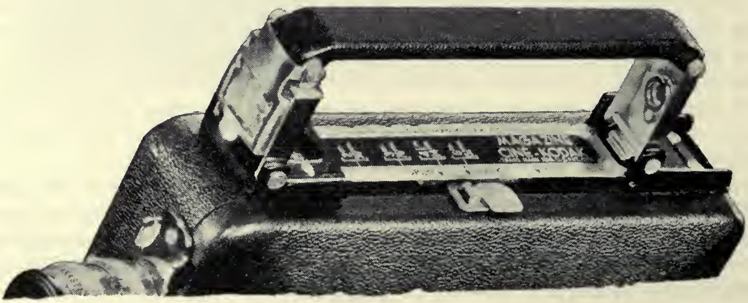

FIG. 4. Combination carrying handle and variable finder system.

lengths are accommodated. The front positive element can be raised out of the way, thus giving a still wider finder field for lenses shorter than one inch.

The sliding of the latch on the camera performs three different functions: it locks the cover, releases the mechanism lock, and opens the sliding magazine shutter. When the camera is not in use, this latch can be set midway, locking both cover and mechanism.

Another novel feature is the "pulse," located below the crank, which beats beneath the user's finger once every half-foot of film. It provides a most convenient method for determining scene length. On the front are the exposure guide plate with its diaphragm markings, and the camera speed lever with graduations marked 8, 16, and 64 frames per second.

Two carrying cases are provided. One is a soft leather case with zipper, for holding the camera only. The other is a sole-leather case for the camera, three additional lenses, and incidental attachments. If preferred, two magazines may be substituted for the lenses.

When designing the camera and all the accessories, no effort was spared to combine richness of appearance with mechanical strength. Magazines are available loaded with four different types of film—panchromatic, supersensitive, regular Kodachrome, and the new type *A* Kodachrome for artificial light.

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J. H. Kurlander
E. Ross
A. Shapiro
A. F. Victor

PAPERS

G. E. Matthews, *Chairman*

C. N. Batsel
L. N. Busch
A. A. Cook
L. J. J. Didiee
M. E. Gillette
E. W. Kellogg
R. F. Mitchell
W. A. Mueller
H. B. Santee
T. E. Shea
P. R. von Schrott
I. D. Wratten

PRESERVATION OF FILM

J. G. Bradley, *Chairman*

J. I. Crabtree
A. S. Dickinson
R. Evans
M. E. Gillette
C. L. Gregory
T. Ramsaye
V. B. Sease
W. A. Schmidt

PROGRESS

J. G. Frayne, *Chairman*

M. Abribat
L. N. Busch
A. A. Cook
R. M. Corbin
J. A. Dubray
R. E. Farnham
E. R. Geib
G. E. Matthews
H. Meyer
V. E. Miller
R. F. Mitchell
G. F .Rackett
P. R. von Schrott
S. S. A. Watkins
I. D. Wratten

PROGRESS AWARD

A. N. GOLDSMITH, *Chairman*

M. C. BATSEL
J. I. CRABTREE
C. DREHER
J. G. FRAYNE

PROJECTION PRACTICE

H. RUBIN, *Chairman*

J. O. BAKER
T. C. BARROWS
F. E. CAHILL
J. R. CAMERON
G. C. EDWARDS
J. K. ELDERKIN
J. J. FINN
E. R. GEIB
A. N. GOLDSMITH
H. GRIFFIN
J. J. HOPKINS
C. F. HORSTMAN
P. A. MCGUIRE
R. MIEHLING
E. R. MORIN
M. D. O'BRIEN
F. H. RICHARDSON
J. S. WARD
V. WELMAN

PROJECTION SCREEN BRIGHTNESS

C. TUTTLE, *Chairman*

A. A. COOK
A. C. DOWNES
D. E. HYNDMAN
W. F. LITTLE
O. E. MILLER
G. F. RACKETT
H. RUBIN
B. SCHLANGER
A. T. WILLIAMS
S. K. WOLF

PUBLICITY

W. WHITMORE, *Chairman*

J. R. CAMERON
J. J. FINN
G. E. MATTHEWS
P. A. MCGUIRE
F. H. RICHARDSON

SOUND

P. H. EVANS, *Chairman*

M. C. BATSEL
L. E. CLARK
F. J. GRIGNON
K. F. MORGAN
O. SANDVIK
E. I. SPONABLE
R. O. STROCK
H. G. TASKER
S. K. WOLF

STANDARDS

E. K. CARVER, *Chairman*

P. ARNOLD
F. C. BADGLEY
M. C. BATSEL
L. N. BUSCH
W. H. CARSON
A. CHORINE
A. COTTET
L. DE FEO
A. C. DOWNES
J. A. DUBRAY
P. H. EVANS
R. E. FARNHAM
C. L. FARRAND
G. FRIEDL, JR.
H. GRIFFIN
R. C. HUBBARD
E. HUSE
C. L. LOOTENS
W. A. MACNAIR
K. F. MORGAN
T. NAGASE
N. F. OAKLEY
G. F. RACKETT
W. B. RAYTON
C. N. REIFSTECK
H. RUBIN
O. SANDVIK
H. B. SANTEE
J. L. SPENCE
A. G. WISE
I. D. WRATTEN

STUDIO LIGHTING

R. E. FARNHAM, *Chairman*

W. C. KUNZMANN	V. E. MILLER	E. C. RICHARDSON
J. H. KURLANDER	G. F. RACKETT	F. WALLER

SECTIONS OF THE SOCIETY

(*Atlantic Coast*)

L. W. DAVEE, *Chairman*

H. G. TASKER, *Past-Chairman*	M. C. BATSEL, *Manager*
D. E. HYNDMAN, *Sec.-Treas.*	H. GRIFFIN, *Manager*

(*Mid-West*)

C. H. STONE, *Chairman*

R. F. MITCHELL, *Past-Chairman*	O. B. DEPUE, *Manager*
S. A. LUKES, *Sec.-Treas.*	B. E. STECHBART, *Manager*

(*Pacific Coast*)

G. F. RACKETT, *Chairman*

E. HUSE, *Past-Chairman*	K. F. MORGAN, *Manager*
H. W. MOYSE, *Sec.-Treas.*	C. W. HANDLEY, *Manager*

HIGHLIGHTS OF THE FALL CONVENTION

SAGAMORE HOTEL, ROCHESTER, N. Y.

OCTOBER 12-15, 1936

In view of the great success of the convention just ended, it is difficult to understand why fourteen years were allowed to elapse between this and the last Convention held at Rochester. Although the number of firms located at Rochester interested in the motion picture business may not be as great as the number to be found in New York, Hollywood, or Chicago, nevertheless, the firms that are located there are of such great importance to the industry and so interested in the activities of the Society that Rochester may well be counted a fourth center of the American motion picture industry. Indeed, it may reasonably be doubted that the success of the Convention would have been as great as it was had it not been for the fine coöperation and collaboration of the Eastman Kodak Company and the Bausch & Lomb Optical Company, and other firms in Rochester active in the industry. In view of these facts, and in view of the fairly large membership of the Society residing in Rochester and vicinity, and in view also of the generally expressed satisfaction with the Convention, it is to be expected that the Society will not again wait as many years before holding its next Convention at Rochester.

Although the total registration was approximately 200, a considerably greater number of persons were in evidence throughout the week, particularly as indicated by the attendance at the technical sessions and at the luncheons, and during the tours through the plants of the Eastman Kodak Company and the Bausch & Lomb Company. It was particularly gratifying to note that the attendance at the technical sessions was extremely good even up to the last hour of the last day.

The program of papers and presentations as actually followed at the sessions was as published on succeeding pages of the JOURNAL.

At noon of the opening day the usual informal get-together luncheon was held, attended by approximately 170 persons. The members were welcomed to Rochester by the Honorable Charles Stanton, Mayor of Rochester, followed by a brief response by President Tasker. Other speakers at the luncheon were Dr. Howard Hanson, Director of the Eastman School of Music, and William H. Roberts, President of the Rochester Engineering Society and Assistant Engineer of the City of Rochester. Mr. William Caderet, Managing Director of the Monroe Amusement Company, and Mr. Lester Pollack, Manager of Loew's "Rochester" theater, were also introduced to the delegates.

On Tuesday at noon the members and guests were very pleasantly entertained at an invitation luncheon given by the Eastman Kodak Company at the Kodak Park plant. Following the luncheon, Mr. C. K. Flint, Manager of the plant, welcomed the Society officially. The party was then divided into small groups for the visits to the Kodak plant and the Research Laboratories.

The Wednesday luncheon at the Bausch & Lomb Optical Company proved to be another pleasant occasion. After the meal President Tasker introduced several

of the officers of the Bausch & Lomb Company, among whom was Edward Bausch, 82-year-old son of one of the founders of the firm and Chairman of the Board. Mr. Bausch spoke briefly of his earlier years with the firm and cordially welcomed the Society to a visit to the plant. A glass-pouring operation, normally conducted in the morning, was held over especially to demonstrate the very interesting process to the Society. A trip through the various departments of the plant and research bureau followed. These two tours probably comprised *the* outstanding events of the Convention, as indicated by the extreme interest of practically all the delegates in the tours and their great desire to avoid missing them. Both tours occupied practically the complete afternoons of Tuesday and Wednesday.

On the evening of Wednesday, October 14th, the Semi-Annual Banquet and Dance of the Society was held at the Oak Hill Country Club. Outstanding guests at the speakers' table were Mr. M. H. Aylesworth, Chairman of the Board of Radio Keith Orpheum and formerly President of the National Broadcasting Company; Dr. Alan Valentine, President of the University of Rochester; Dr. C. E. Kenneth Mees, Vice-President in charge of Research and Development of the Eastman Kodak Company; Mr. Albert F. Sulzer, Vice-President and Assistant General Manager of the Eastman Kodak Company; Mr. Carl S. Hallauer, Vice-President of Bausch & Lomb Optical Company; Mr. Lee McCann, Secretary of Stromberg-Carlson Telephone Manufacturing Company; Mr. H. De Jong, Chief Engineer of Philips Glowlampworks, Eindhoven, Holland; and Mr. C. Connio-Santini, special delegate to the Convention from the Cinè Club of Buenos Aires, Argentina.

Also seated at the speaker's table were Mr. H. G. Tasker, *President* of the Society; Dr. Alfred N. Goldsmith, *Past-President;* Mr. S. K. Wolf, *President-Elect;* Mr. J. I. Crabtree, *Editorial Vice-President;* Mr. K. F. Morgan, *Manager* of the Pacific Coast Section; and Mr. J. A. Ball, of the Technicolor Corporation, Hollywood.

Following the Banquet, President Tasker spoke a few brief words of welcome, and then announced the results of the recent election of officers of the Society for 1937 as follows: *President,* Mr. S. K. Wolf; *Executive Vice-President,* Mr. H. G. Tasker; *Editorial Vice-President,* Mr. J. I. Crabtree; *Convention Vice-President,* Mr. W. C. Kunzmann; *Secretary,* Mr. J. Frank, Jr.; *Treasurer,* Mr. L. W. Davee; and *Governors at Large,* Mr. M. C. Batsel and Dr. A. N. Goldsmith. Other officers of the Society remain unchanged in view of the two-year tenure of office.

President Tasker then requested Dr. A. N. Goldsmith to read the Journal Award Committee's citation on the work of Edward W. Kellogg, this year's nominee of the Journal Award Committee. The Award consists of a suitably inscribed and illuminated parchment certificate, accompanied by a cash award of fifty dollars. After receiving the certificate from President Tasker, Mr. Kellogg expressed his appreciation in a few well chosen and appropriate words.

President Tasker next introduced Dr. L. A. Jones who read, on behalf of the Progress Award Committee, a citation reviewing the contributions of Dr. C. E. K. Mees, of the Eastman Kodak Company, to motion picture photography and to the photographic art and science in general. The Progress Medal, which has been illustrated from time to time in the JOURNAL, was then presented to Dr. Mees by President Tasker; whereupon Dr. Mees responded with a short account of his interest in the science of photography when he first began his researches

in 1903, and of the changes and developments that have taken place since that time.

The complete citations and responses for both awards, as well as other banquet proceedings, will be published in a subsequent issue of the JOURNAL.

Following the presentation of the Awards, the guest speaker of the evening, Mr. M. H. Aylesworth, Chairman of the Board of Radio Keith Orpheum and Radio Pictures, and formerly President of the National Broadcasting Company, presented an interesting address on "The Relation of Radio Broadcasting to Motion Pictures and the Theater."

After the proceedings described above, the remainder of the evening was spent in dancing and enjoying the entertainment provided by Mr. W. C. Kunzmann, *Convention Vice-President*, who also acted as master of ceremonies. Featured on the program was Miss Irene Gedney, concert pianist, and Mr. Jack Driscoll, radio impersonator. Mr. Driscoll concluded his presentation with an impersonation of one of our best known members, Mr. F. H. Richardson.

PAPERS PROGRAM

As pointed out previously, one of the important factors contributing to the success of the Convention was that of holding the Convention in the home city of the Eastman Kodak Company and the Bausch & Lomb Company. For that reason it can be expected that an important part of the Papers Program was contributed by members of those organizations, not to speak of the tours through the plants, which undoubtedly drew a considerable number of the delegates to the Convention.

One of the outstanding events of the program was the Monday evening lecture-demonstration by Dr. C. E. Kenneth Mees on the subject of color photography, held at the Eastman Theater. In his lecture Dr. Mees traced the general principles of the various systems of color photography, both additive and subtractive, and showed the relations of these systems to each other. He also demonstrated, by means of 16-mm. color pictures, examples of work produced by the different systems. Included, among others, were examples of Gasparcolor, Technicolor, Kodacolor, Dufaycolor, and Kodachrome. Dr. Mees also gave a most interesting paper on "Color Photography" as a requirement in connection with the Progress Medal Award.

Considerable interest was shown in the paper by J. Frank, Jr., on "The Schwarzkopf Method of Identifying Criminals." This method had been developed by Colonel Schwarzkopf, recently of the New Jersey State Police Department, and has attracted considerable attention.

A lively discussion followed the reading of Dr. Hanson's paper on "Science and the Musician," which described some of the hardships as well as the benefits felt by musicians since the introduction of sound motion pictures. Considerable interest was aroused by the demonstration staged by Mr. R. H. Heacock on a method of locating a desired groove on a phonograph record, and by Messers. Richardson and Hover on the use of a neon tube oscilloscope as a utility instrument in projection.

The session of the morning of Tuesday, October 13th, was held in its entirety in the auditorium of the Eastman Research Laboratories. The meeting was

opened by a brief address of welcome by Dr. S. E. Sheppard, Associate Director of the Laboratories, and was followed by a symposium of papers dealing with the manufacture of motion picture film; the stability and aging properties of film; storage of film records in libraries; and a paper dealing with fire prevention in the motion picture industry and one on the projection of lenticular color films.

Wednesday morning was devoted to a symposium on the subjects of lighting and optics, and included an interesting paper by J. A. Norling on the subject of "Trick and Process Cinematography." The paper by E. C. Richardson, of Hollywood, on the subject of "High-Intensity Arc Spotlamps for Motion Picture Production" also aroused considerable interest.

The morning of Thursday, October 15th, was devoted to the description of new equipment and apparatus. The film-editing machine embodying optical intermittent projection, described and exhibited by J. L. Spence, probably attracted the most attention at this symposium, although the demonstration of the triode tube by F. E. Eldredge and H. F. Dart aroused considerable interest also. The paper on the "Third-Dimensional Effect in Animated Cartoons," described by J. E. Burks, of Fleischer Studios, was accompanied by a short picture demonstrating the effect of rotating the perspective lines before the camera instead of allowing them to remain fixed, as is the usual procedure in producing cartoons.

ACKNOWLEGMENTS

Credit for the success of the Convention was generally due to the efforts of Mr. W. C. Kunzmann, *Convention Vice-President;* Mr. J. I. Crabtree, *Editorial Vice-President;* Mr. G. E. Matthews, *Chairman*, Papers Committee; Mr. H. Griffin and J. Frank, Jr., in charge of projection facilities; Mr. E. P. Curtis, *Chairman*, Local Arrangements Committee; Mr. C. M. Tuttle, *Chairman*, Transportation Committee; Mr. I. L. Nixon, *Chairman*, Banquet Committee; Mrs. L. A. Jones, in charge of the Ladies, activities; Mr. E. R. Geib, *Chairman*, Membership Committee; Mr. L. M. Townsend, *President*, Rochester Local No. 253 IATSE, and the officers and members of Local No. 253; Mr. W. Whitmore, *Chairman*, Publicity Committee; Mr. Franklin Ellis, who rendered very valuable assistance in respect to publicity.

The Eastman Kodak Company and the Bausch & Lomb Company, and the officials and employees thereof, should be especially thanked for the splendid facilities provided and the great cordiality with which the members were received at the plants. Among other companies who contributed to the Convention were National Carbon Co., Inc., International Projector Corp., National Theater Supply Co., Raven Screen Co., and Harry H. Strong Co., all of whom collaborated in making available the projection equipment used during the technical sessions at the Sagamore Hotel. In addition, Electro-Acoustic Products Company is to be thanked for the installation of the public address system.

The courtesy of radio station WHAM for broadcasting an address by President Tasker on Monday evening is hereby acknowledged, and thanks are due to Mr. Lester Pollack, of Loew's Theaters, Inc., for courtesy cards to the "Rochester" Theater, and to Mr. William Caderet, Manager of the Monroe Museum Company for courtesy cards to the members for admission to the "Palace," "Century," and "Regent" Theaters.

PROGRAM

MONDAY, OCTOBER 12th

9:00 a. m. **Registration; Sagamore Hotel Roof.**

10:00 a. m. *Sagamore Roof;* **Business and General Session.**
Opening Remarks by President H. G. Tasker.
Report of the Convention Committee; W. C. Kunzmann, *Convention Vice-President.*
Society Business.
Election of Officers for 1937.
Report of the Secretary; J. H. Kurlander.
Report of the Membership Committee; E. R. Geib, *Chairman.*
"Slide Rule Sketches of Hollywood;" H. G. Tasker, Universal Pictures Corp., Universal City, Calif.
"The Development of the Art and Science of Photography in the Twentieth Century;" (*Illustrated*) C. E. K. Mees, Eastman Kodak Company, Rochester, N. Y.

12:30 p. m. *Main Dining Room;* **Informal Luncheon.**
For members and guests. Address of Welcome by the Hon. Charles Stanton, Mayor of Rochester; Response by President Tasker.

2:00 p. m. *Sagamore Hotel Roof;* **Sound and Apparatus Session.**
"Science and the Musician;" H. Hanson, Director, Eastman School of Music, Rochester, N. Y.
Report of the Sound Committee; P. H. Evans, *Chairman.*
"A Record Word-Spotting Mechanism;" R. H. Heacock, RCA Manufacturing Co., Inc., Camden, N. J. (*Demonstration.*)
"Modern Loud Speaking Telephones and Their Developments;" C. Flannagan, R. Wolf, and W. C. Jones, Electrical Research Products, Inc., New York, N. Y.
"A Review of the Quest for Constant Speed;" E. W. Kellogg, RCA Manufacturing Co., Inc., Camden, N. J.
Sound Apparatus Symposium.
"The Schwarzkopf Method of Identifying Criminals;" J. Frank, Jr., International Projector Corporation, New York, N. Y. (*Demonstration.*)
"A Neon Type Volume Indicator;" S. Read, Jr., RCA Manufacturing Co., Inc., Camden, N. J. (*Demonstration.*)
"A Neon Tube Oscilloscope as a Utility Instrument for the Projection Room;" F. H. Richardson, *Motion Picture Herald*, New York, N. Y., and T. P. Hover, Warner's Ohio Theater, Lima, Ohio (*Demonstration.*)
"A New High-Quality Portable Film Recording System;" F. L.

Hopper, E. C. Manderfeld, and R. R. Scoville, Electrical Research Products, Inc., New York, N. Y.

"A New High-Quality Film Reproducer;" J. C. Davidson, Electrical Research Products, Inc., New York, N. Y.

7:00 p. m. *Station WHAM Studios;* **Radio Interview.**

"A Glimpse behind the Screens of Hollywood;" H. G. Tasker, Universal Pictures Corp., Hollywood, Calif., and William Fay, Station WHAM, Rochester, N. Y.

8:15 p. m. *Eastman Theater;* **Special Lecture Demonstration.**

"Color Photography" (with demonstrations and motion pictures); Dr. C. E. K. Mees, *Vice-President in Charge of Research and Development,* Eastman Kodak Company, Rochester, N. Y.

TUESDAY, OCTOBER 13th

10:00 a. m. *Auditorium, Kodak Research Laboratories;* **General Technical Session.**

"The Kodak Research Laboratories;" S. E. Sheppard, Eastman Kodak Co., Rochester, N. Y.

"Manufacture of Motion Picture Film;" E. K. Carver, Eastman Kodak Co., Rochester, N. Y.

"Stability of Motion Picture Film as Determined by Accelerated Aging;" J. R. Hill and C. G. Weber, National Bureau of Standards, Washington, D. C.

"The Care of Slide-Films and Motion Picture Films in Libraries;" C. G. Weber and J. R. Hill, National Bureau of Standards, Washington, D. C.

"Fire Prevention in the Motion Picture Industry;" H. Anderson, Paramount Pictures, Inc., New York, N. Y.

"The Projection of Lenticular Color Films;" J. G. Capstaff, O. E. Miller, and L. S. Wilder, Eastman Kodak Co., Rochester, N. Y. (*Demonstration.*)

1:10 p. m. **Invitation Luncheon at the Kodak Park Plant of the Eastman Kodak Company.**

2:00 p. m. Inspection Tour of Kodak Park and the Kodak Research Laboratories.

WEDNESDAY, OCTOBER 14th

9:30 a. m. *Sagamore Hotel Roof;* **Optics and Lighting Session.**

"Effect of Lens Aberrations upon Image Quality;" W. B. Rayton, Bausch & Lomb Optical Co., Rochester, N. Y.

"Mercury Arcs of Increased Brightness and Efficiency;" L. J. Buttolph, General Electric Vapor Lamp Co., Hoboken, N. J. (*Demonstration.*)

"Effect of Light-Source Size with 16-Mm. Optical Systems;" G. Mili, Westinghouse Lamp Co., Bloomfield, N. J.

Report of the Studio Lighting Committee; R. E. Farnham, *Chairman.*

"Recent Developments of High-Intensity Arc Spotlamps for Motion Picture Production;" E. C. Richardson, Mole-Richardson, Inc., Hollywood, Calif.

"Trick and Process Cinematography;" J. A. Norling, Loucks & Norling Studios, New York, N. Y. (*Demonstration.*)

Demonstration Film Showing Several Applications of Photography with Polarized Light. (*Courtesy of American Society of Cinematographers, Inc., Hollywood, Calif.*)

1:10 p. m. **Invitation Luncheon at Bausch & Lomb Optical Company.**

2:00 p. m. Inspection Tour of Bausch & Lomb Plant and the Scientific Bureau.

7:30 p. m. *Oak Hill Country Club;* **Semi-Annual Banquet.**

Presentation of SMPE Journal Award.

Presentation of SMPE Progress Medal.

Address: "The Relation of Radio Broadcasting to Motion Pictures and the Theater," by M. H. Aylesworth, Chairman of the Board of Radio Keith Orpheum and Radio Pictures, formerly President of the National Broadcasting Company.

Dancing and entertainment.

THURSDAY, OCTOBER 15th

9:30 a. m. *Sagamore Hotel Roof;* **Equipment Session.**

Apparatus Symposium.

- "A Film-Editing Machine Embodying Optical Intermittent Projection;" J. L. Spence, Akeley Camera, Inc., New York, N. Y.
- "New Recording Equipment;" D. Canady, and "An Improved Reel-End Alarm;" D. Canady and V. Welman, Canady Sound Appliance Co., Cleveland, Ohio.
- "Three-Wire Direct-Current Supply for Projector Arcs;" C. C. Dash, Hertner Electric Co., Cleveland, Ohio.
- "A Demonstration Triode Tube;" F. E. Eldredge and H. F. Dart, Westinghouse Lamp Co., Bloomfield, N. J. (*Demonstration.*)

Report of the Non-Theatrical Equipment Committee, R. F. Mitchell, *Chairman.*

Report of the Standards Committee; E. K. Carver, *Chairman.*

"A Third-Dimension Effect in Animated Cartoons;" J. E. Burks, Fleischer Studios, New York, N. Y. (*Demonstration*).

"The Use of Visual Equipment in Elementary and Secondary Schools;" C. M. Koon, Office of Education, U. S. Department of the Interior, Washington, D. C.

"Medical Motion Pictures in Color;" R. P. Schwartz, M.D., School of Medicine, University of Rochester, and H. B. Tuttle, Eastman Kodak Co., Rochester, N. Y. (*Demonstration.*)

2:00 p. m. *Sagamore Hotel Roof;* **Laboratory Session.**

"Note on the Use of an Automatic Recording Densitometer;" C. Tuttle and M. E. Russell, Eastman Kodak Company, Rochester, N. Y.

"A Developing Machine for Sensitometric Work;" L. A. Jones, M. E. Russell, and H. R. Beacham, Eastman Kodak Co., Rochester, N. Y.

"Some Data Regarding Dimensions of the Picture Image in 16-Mm. Reduction Prints;" G. Friedl, Jr., Electrical Research Products, Inc., New York, N. Y.

"Influence of Sprocket Hole Perforations upon the Development of Adjacent Sound-Track Areas;" J. G. Frayne and V. Pagliarulo, Electrical Research Products, Inc., Los Angeles, Calif.

"A Practical Method for Dry Hypersensitization of Photographic Materials;" F. Dersch and H. H. Duerr, Agfa Ansco Corporation, Binghampton, N. Y.

"A Brief Survey of the Physics and Technology of the Berthon-Siemens Color Process;" E. Gretener, Siemens & Halske A. G., Siemensstadt, Germany.

Open Forum on Society Problems.

5:00 p. m. Adjournment of the Convention.

SOCIETY ANNOUNCEMENTS

NEXT CONVENTION AT HOLLYWOOD, CALIF.

At the meeting of the Board of Governors, on October 11th, it was decided that the next Convention of the Society will be held at Hollywood, Calif., May 24th–27th, inclusive, with headquarters at the Hotel Roosevelt. The Papers Committee, under J. I. Crabtree, *Editorial Vice-President*, and G. E. Matthews, *Chairman* of the Committee, have already proceeded to solicit an outstanding group of papers and presentations, and promise that the Convention will be an unusual one. The usual apparatus exhibit will be held, and various inspection trips and sight-seeing tours will be arranged.

The Board of Managers of the Pacific Coast Section, G. F. Rackett, *Chairman*, is collaborating with W. C. Kunzmann, *Convention Vice-President*, in arranging the facilities and other important features of the Convention. Complete details will be published in succeeding issues of the JOURNAL. All members are urged to make plans in advance for attending the Convention, perhaps by arranging their vacations to accord with the trip. Special summer tourists' rates will be effective on all railroads after May 15th.

OFFICERS FOR 1937

On the opening day of the Rochester Convention, October 12th, the ballots returned by the membership of the Society for voting upon the officers for 1937 were counted, the results being as follows:

President: S. K. WOLF
Executive Vice-President: H. G. TASKER
Editorial Vice-President: J. I. CRABTREE
Convention Vice-President: W. C. KUNZMANN
Secretary: J. FRANK, JR.
Treasurer: L. W. DAVEE
Governors: M. C. BATSEL
A. N. GOLDSMITH

The President, all the Vice-Presidents, and the two Governors were elected for two-year terms; the Secretary and Treasurer for one-year terms. Other officers and Governors of the Society, whose terms have yet one year to run, are:

Engineering Vice-President: L. A. JONES
Financial Vice-President: O. M. GLUNT
Governors: A. S. DICKINSON
H. GRIFFIN
A. C. HARDY

Elections of the Chairmen of the three Sections of the Society—Atlantic Coast, Midwest, and Pacific Coast—are yet in progress, and the results will be announced as soon as they are known.

ADMISSION FEES

At the meeting of the Board of Governors on October 11th it was proposed that the regulation in the By-Laws requiring Admission fees of applicants for Active and Fellow membership in the Society be abrogated. On the following day, October 12th, the proposal was ratified by the General Society in meeting at the Sagamore Hotel, Rochester. It is hoped that the suspension of these fees will result in an increase in the number of applicants for membership in these grades.

16-MM. SOUND-FILM STANDARDS

Culminating the long series of discussions on 16-mm. sound-film standards, beginning in 1934 at Stresa, Italy, and followed by meetings at Berlin and Paris, the International Standards Association has formally adopted the SMPE 16-mm. sound-film standards as world standards. S. K. Wolf, *Executive Vice-President* of the Society, was the representative of the American Sectional Committee on Motion Pictures at the Budapest Conference. The results of the Conference, which was held on September 5th, as contained in a circular letter from the Deutscher Normenausschuss to the nineteen national standardizing bodies comprising the ISA, are as follows:

The Committee of the ISA formerly known as "Technical Committee ISA 36, Photography and Cinematography" is henceforth to be known as "Technical Committee ISA 36 Cinematography." The Committee will deal only with questions of cinematography, and not with questions of photography.

The national organizations of the countries concerned are requested to conform to the standards of the American system known as "SMPE." It is understood that these standards, which relate to black-and-white films, shall apply in their entirety to color films on all occasions where the technical principles of the color reproduction processes employed are not definitely incapable of such application.

In addition, the national organizations formally undertake not to modify, in any manner or in regard to any detail, during a period of at least ten years from the present date, the standards adopted at this Conference.

If, for any reasons rendered necessary by some new technical development, any national organization feels that the existing standards should be modified, such modification may be made only after a decision arrived at under the auspices of the ISA.

The delegates present at the Conference agreed to arrange in their respective countries, through the intermediary of their national organizations, the widest possible publicity for the decisions reached at the Conference, in order that they may become effective with the least possible delay in consideration of the conditions peculiar to each country.

The following-named representatives of the various national standardizing associations were present at the Budapest Conference:

U. S. A.	S. K. Wolf, *Executive Vice-President*, SMPE.
Great Britain	M. Neville Kearney, British Standards Institution.
France	J. Demaria and Henri Cottet, Association Française de

	Normalisation et Chambre Syndicale des Industries Techniques de la Cinematographie.
Germany	H. WARNCKE, Deutscher Fachnormenausschus für Kinotechnik.
Netherlands	NILLESEN and A. VON KREVELD, Hoofdcommisie voor Normalisatie.
Sweden	FOLKE KINDGREN, Sveriges Standardiseringskommission.
Czechoslovakia	ING. JAN CHARUZA, CSN.
Hungary	ING. JOHANN BRUCKNER, Magyar Szabvanyugyi Intezet.
Denmark	H. E. GLAHN, Dansk Standardizeringsraad.
Italy	Corrado Picone tenente colonello.
ISA	DR. W. RAHTS, *Chairman*, ISA-Committee 36.
	DR. O. FRANK, *Secretary*, ISA-Committee 36.
	A. HUBER-RUF, *General Secretary*, ISA.

ADMISSIONS COMMITTEE

At a recent meeting of the Admissions Committee, at the General Office of the Society, the following applicants for membership were admitted to the Associate grade:

AKINS, G.
Dallastown,
RFA 1, Pa.

BARROWMAN, G. D.
Victoria Museum,
Ottawa, Canada

BOOTH, J. H.
1033 North Shore Ave.
Chicago, Ill.

CAPWELL, R. I.
Arnold's Neck
Apponaug, R. I.

CHAMBERLIN, M. H.
3617 Empire Drive
Los Angeles, Calif.

CLARKE, C. A.
10 University Ave.
Chatham, N. J.

CLEBURNE, E. W.
41 McIntosh St.
Gordon, Sydney, Australia

DE HASS, J.
Philips Gloeilampenfabrieken
Cinema Department
Eindhoven, Holland

DENT, E. C.
RCA Manufacturing Co.
Camden, N. J.

DEWEY, H. H.
P. O. Box 147
Kenosha, Wis.

DORMOND, T. E.
5553 Locust St.
Philadelphia, Pa.

EBLING, F.
22 Belgravia Road
North End, Portsmouth, England

FRANKLIN, C. S.
330 N. Sweetzer Ave.
Los Angeles, Calif.

HERZIG, L.
868 E. Seventh St.
Brooklyn, N. Y.

HOWARD, B.
3000 Ramsey Tower
Oklahoma City, Okla.

JONES, H.
Mancos, Colo.

LATTE, H.
Plaza Cataluna 9
Barcelona, Spain

LAURENZ, C.
Lima 1321
Buenos Aires, Argentina

OFFENHAUSER, W. H., JR.
4 W. 43d St.
New York, N. Y.

OLDS, E. M., JR.
1922¼ Fifth Ave.
Los Angeles, Calif.
ROBIN, E.
Rue de la Croix Blanche
France
ROUND, H. J.
6 Aldwych
London, England
RUPE, R.
345 Clermont St.
Denver, Colo.
TURNER, R. T.
Dictograph Products Co., Inc.
580 Fifth Ave., New York, N. Y.
WALTERS, L. H.
2112 Payne Ave.
Cleveland, Ohio
WEI, H. R.
University of Nanking
Nanking, China
WILLIAMS, E.
138 Tolworth Rise
Surbiton, Surrey, England
WILSON, R.
200 Film Bldg.
Cleveland, Ohio
YOUNG, F. W.
3336 Canfield Ave.
Palms, Calif.
ZENTNER, ING. K. J.
Prague II
Vacl, nam. 62
Czechoslovakia

In addition, the following applicants have been admitted by vote of the Board of Governors to the Fellow and Active grades:

DINA, A. (*M*)
33 Washington Sq., W.
New York, N. Y.
HARRIS, S. (*F*)
Society of Motion Picture Engineers
Hotel Pennsylvania
New York, N. Y.
HINES, E. G. (*F*)
International Projector Corp.
90 Gold St.
New York, N. Y.
SORANI, V. (*M*)
Zeiss Ikon A. G. Dresda
Via Carlo Tenca, 22
Milan, Italy
WARNCKE, H. (*F*)
Klangfilm, Inc.
Berlin, Germany
WHITE, L. T. (*M*)
9A Selborne-Yds.
Hendon Central N. W. 4
England

JOURNAL

OF THE SOCIETY OF

MOTION PICTURE ENGINEERS

Volume XXVII | **DECEMBER, 1936** | **Number 6**

CONTENTS

JOURNAL
OF THE SOCIETY OF
MOTION PICTURE ENGINEERS

SYLVAN HARRIS, EDITOR

Subscription to non-members, $8.00 per annum; to members, $5.00 per annum, included in their annual membership dues; single copies, $1.00. A discount on subscriptions or single copies of 15 per cent is allowed to accredited agencies. Order from the Society of Motion Picture Engineers, Inc., 20th and Northampton Sts., Easton, Pa., or Hotel Pennsylvania, New York, N. Y.

Published monthly at Easton, Pa., by the Society of Motion Picture Engineers.

Publication Office, 20th & Northampton Sts., Easton, Pa.

General and Editorial Office, Hotel Pennsylvania, New York, N. Y.

Entered as second class matter January 15, 1930, at the Post Office at Easton, Pa., under the Act of March 3, 1879.

See p. 710 for Technical Committees

PROCEEDINGS OF THE SEMI-ANNUAL BANQUET OF THE SOCIETY OF MOTION PICTURE ENGINEERS

ROCHESTER, N. Y.
OCTOBER 14, 1936

About 200 members and guests of the Society assembled at the Fall, 1936, Semi-Annual Banquet held at the Oak Hill Country Club, just outside Rochester. Guests at the speakers' table included Mr. M. H. Aylesworth, Chairman of the Board of Radio Keith Orpheum, and formerly Chairman of the Board of the National Broadcasting Company; Dr. Alan Valentine, President of the University of Rochester; Dr. C. E. Kenneth Mees, Vice-President in charge of research and development of the Eastman Kodak Company; Mr. Albert F. Sulzer, Vice-President and Assistant General Manager of the Eastman Kodak Company; Mr. Carl S. Hallauer, Vice-President of Bausch & Lomb Optical Company; Mr. Lee McCann, Secretary of Stromberg-Carlson Telephone Manufacturing Company; Mr. H. D. De Jong, Chief Engineer of Philipsglowlampworks, Eindhoven, Holland; and Mr. C. Connio Santini, special delegate to the Convention from the Ciné Club of Buenos Aires, Argentina.

Also seated at the table were Mr. Homer G. Tasker, President of the Society; Dr. Alfred N. Goldsmith, Past-President; Mr. S. K. Wolf, President-Elect; Mr. J. I. Crabtree, Editorial Vice-President; Mr. K. F. Morgan, of the Board of Managers of the Pacific Coast Section; and Mr. J. A. Ball, of Technicolor Corporation, Hollywood.

After a period of dinner-dance music the guests at the speakers' table were introduced one after another, with appropriate words, by President Tasker, following which announcement was made of the results of the election of Officers of the Society for 1937, the ballots having been counted on the opening day of the Convention, Monday, October 12th. As announced by President Tasker, these results were as follows:

President: S. K. Wolf
Executive Vice-President: H. G. Tasker
Editorial Vice-President: J. I. Crabtree
Convention Vice-President: W. C. Kunzmann
Secretary: J. Frank, Jr.
Treasurer: L. W. Davee
Governors: M. C. Batsel
A. N. Goldsmith

The President, all the Vice-Presidents, and the two Governors were elected for two-year terms; the Secretary and Treasurer for one-year terms. Other Officers and Governors of the Society whose terms have yet one year to run are:

Engineering Vice-President: L. A. JONES
Financial Vice-President: O. M. GLUNT
Governors: A. S. DICKINSON
H. GRIFFIN
A. C. HARDY

Elections of the Chairmen of the three Sections of the Society—Atlantic Coast, Mid-West, and Pacific Coast—are yet in progress, and the results will be announced as soon as they are known.

After making sincere acknowledgment of the coöperation of the many persons and firms that had contributed to the success of the Convention (which names have been listed in the November issue of the JOURNAL), President Tasker proceeded to describe the nature and purposes of the annual Awards of the Society, namely, the Progress Medal and the Journal Award. Tracing the historical development of the Awards and describing briefly the symbolism of the designs on the Progress Medal, he called upon Dr. Alfred N. Goldsmith, Past-President of the Society, to read a citation of the work of Mr. Edward Washburn Kellogg, whom the Journal Award Committee and the Board of Governors of the Society had selected as the recipient of the Award for 1936.

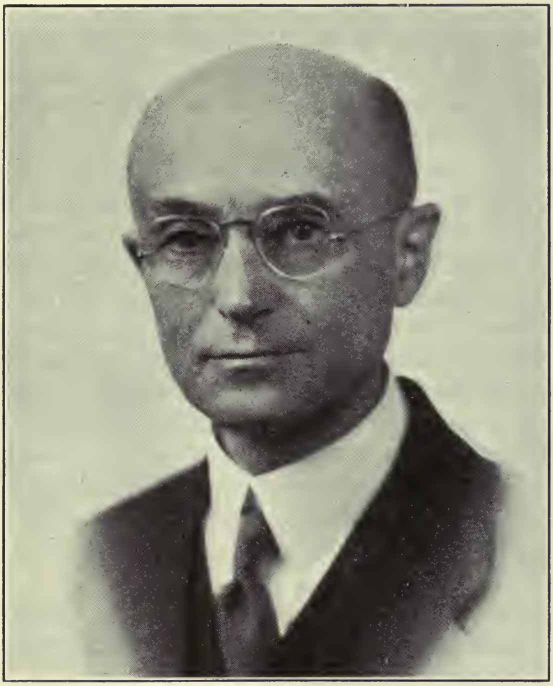
CITATION OF THE WORK OF EDWARD WASHBURN KELLOGG

ALFRED N. GOLDSMITH

It is my privilege to announce that a paper by Mr. Edward W. Kellogg has won the Journal Award of the Society of Motion Picture Engineers for 1935. I deem it appropriate now to give you some information as to Mr. Kellogg's professional career, his contributions to technical progress, and his scientific attitude.

Thirty years ago he was graduated as a civil engineer from Princeton University, later studying mechanical and electrical engineering at Cornell University. From his first employment with a great public utility company in Chicago, he turned to instruction in elec-

trical engineering at the Universities of Missouri, Texas, and Ohio. Shortly after the entry of our nation into the World War, he left the academic world and joined the Research Laboratory of the General Electric Company, at Schenectady, to assist in submarine-detection work. Thus the exigencies of war brought about the beginning of a career of industrial research and engineering notable not only for the importance of its accomplishments, most of which were either



Edward Washburn Kellogg

directly or indirectly related to the sound motion picture art, but also for its versatility.

Mr. Kellogg very soon displayed the scientific originality and thoroughness for which he later became noted. A noteworthy advance occurred in radio broadcasting when there appeared upon the market in 1925 an a-c. operated receiver incorporating a dynamic cone loud speaker and an amplifier with adequate power to drive

the speaker, this valuable product being the result of the fundamental researches of Mr. Kellogg and his associate, C. W. Rice.

Commercial radio communication has benefited considerably by the early work of Messrs. Rice and Kellogg on directional antennas, and, in particular, by their theoretical work in coöperation with H. H. Beverage on the system known as the "wave" or "Beverage" antenna.

Electrical reproduction of phonograph records reached commercial realization in considerable measure through Mr. Kellogg's development, in 1926, of the magnetic pick-up, in substantially the same form as is still found in home phonographs. He was also active in the development of electrical methods of recording on wax for the Brunswick Company.

Since the advent of sound motion pictures, Mr. Kellogg has been concerned with nearly every technical phase of the art, at the laboratories of the RCA Manufacturing Company at Camden. From the beginning he has urged the importance of speed constancy in the reproducing mechanism to prevent "wows" or "flutter," and has been most ingenious in devising means of achieving such constancy. His studies of optical systems, film resolution, and printing mechanisms have been instrumental in the development of high-quality film recording, and may be said to have become classic contributions.

The paper that has earned for him the Journal Award, "A Comparison of Variable-Density and Variable-Width Systems," is itself an eloquent demonstration of Mr. Kellogg's wide acquaintance with the problems of recording sound upon film, and of his skill and open-mindedness in fundamental analysis.

It gives me real gratification now to present Mr. Kellogg to President Tasker, who will present the Journal Award of the SMPE to him. I am doubly pleased that this honor should come to one who combines in such outstanding degree original thinking, scientific thoroughness, technical skill, and manly candor and courage.

Amid enthusiastic applause from the audience, Mr. Kellogg approached the speakers' table, where President Tasker presented to him the Journal Award certificate, addressing him as follows:

"Mr. Kellogg, it is a very great pleasure to present to you this certificate, which I should like to read for the benefit of the members of the Society. Upon this scroll is inscribed this legend: *This is to certify that the paper entitled 'A Comparison of Variable-Density and*

Variable-Width Systems,' by Edward Washburn Kellogg, has been designated by the Journal Award Committee as the most outstanding paper originally published in the Journal of the Society of Motion Picture Engineers during the year 1935."

Accepting the certificate from President Tasker, Mr. Kellogg responded in the following words:

"Mr. President, I thank you. And Ladies and Gentlemen—Dr. Goldsmith was so kind as to speak of my candor and readiness to tell the truth. It really is a great luxury, once in a while, to say what one knows is so. I am going to take this occasion to indulge in a little of that luxury and give you the straight story of what it was all about.

"The happiest experiences that come to us are often the results of a course of action that we would have liked to avoid. I certainly did not very gladly undertake to write the paper that had such a happy outcome for me. It all came about through Max Batsel's persuasive way of telling one that a certain thing ought to be done. My hesitancy was partly because the subject was, as many of you know, a decidedly controversial one. But I was encouraged by being reminded that it was not a presidential election year, and that it would be all right to tell the truth.

"For a good many years I have been studying distortion in sound. Throughout it all I have been profoundly impressed with the crudeness of our man-made sound devices and with how wonderfully our God-given powers of perception, interpretation, and imagination fill in the gaps.

"Although officially, of course, I may not admit that any of the products or processes sponsored by the company for which I work give rise to any distortion, we all know that that is not true. It is only $99^{44}/_{100}$ per cent true. In this matter of variable-density *vs.* variable-width systems, we all know that both of them can produce plenty of distortion. If some of you may not happen to know what the technical terms "variable-density" and "variable-width" mean, let me assure you that it is entirely sufficient for you to know that both of them are *variable*, as attested by many a headache.

"Having undertaken to assume a role resembling in some respects that of referee in a game between rival teams, the first difficulty I encountered was that it appeared to be necessary for me to learn something about the subject, which was fortunately made possible,

in great measure, by the many valuable papers contributed to this Society by earlier authors.

"The real gist of what I found out after prolonged study was that I should say to the members of both camps, 'Gentlemen, the other fellow's system is so bad, so full of distortion, that only by the grace of heaven can people understand anything that is said.'

"I want to express my appreciation to the Society for this Award, and to the Committee for what I know must have been a lot of hard work, and I am grateful for the very kind things that have been said tonight. I want to say one more thing: that the meetings of this Society are a profound pleasure to all us men. I do not know of any group of men where there are so many authorities on so many different subjects in which one may happen to be interested, and from whom we can find out things that we want to know. We revel in it; and you ladies who come here for a good time do not know what fun your husbands are really having."

It is a requirement of the Journal Award that honorary mention be made of not more than five outstanding papers originally published in the Journal during the corresponding year. The following are the papers thus given honorable mention this year:

"Flutter in Sound Records," by T. E. Shea, W. A. MacNair, and A. Subrizi.

"The Photographic Effectiveness of Carbon Arc Studio Light-Sources," by F. T. Bowditch and A. C. Downes.

"A Mechanical Demonstration of the Properties of Wave Filters," by C. E. Lane.

"Simple Theory of the Three-Electrode Vacuum Tube," by H. A. Pidgeon.

It is also a requirement of the regulations pertaining to the Journal Award that the names of the recipients of previous Awards be published annually in the JOURNAL:

"An Introduction to the Experimental Study of Visual Fatigue," by Peter Andrew Snell (1933).

"Reciprocity Law Failure in Photographic Exposure," by Loyd Ancile Jones and Julian Hale Webb (1934).

Continuing the presentation of the Society Awards, President Tasker called upon Dr. L. A. Jones to read a citation of the work of Dr. C. E. Kenneth Mees, who had been selected by the Progress Award Committee and the Board of Governors of the Society as the recipient of this Award for 1936:

CITATION OF THE WORK OF CHARLES EDWARD KENNETH MEES

LOYD A. JONES

It is indeed a privilege that I value most highly, and an honor that I deeply appreciate, to appear before you this evening charged with the duty of calling to your attention some of the contributions to the

Charles Edward Kenneth Mees

art and science of motion picture photography of the man who is about to receive the Progress Medal of the Society. This medal is awarded for outstanding and distinctive achievement in the field of

motion picture photography, and is the highest award within the power of this Society to bestow.

Charles Edward Kenneth Mees was born in Wellingborough, England, May 26, 1882, the son of Charles Edward Mees, a Wesleyan minister, and Ellen Jordan. His paternal grandfather was Charles Mees, a manufacturer residing in Lufton, Bedfordshire. His great grandfather and great-great grandfather on his mother's side were Wesleyan ministers.

After elementary school training he went to Kingswood School, Bath, the school founded by John Wesley for the sons of Wesleyan ministers. He then attended Harrowgate College for one year, and later went to St. Dunstan's College, Catford, a technical college, where he specialized in scientific work in preparation for University College, London, which he entered in 1900 as a student under Sir William Ramsay, then professor of general chemistry at University College. He was graduated with the degree of Bachelor of Science by research at University College in 1903, and received the degree of Doctor of Science in chemistry from the University of London in 1906 for a thesis on the sensitometry of photographic plates.

In the same year he joined the firm of Wratten and Wainwright, Ltd., of Croydon, England, as joint managing director. This concern was engaged in the manufacture of photographic dry plates. While with them he developed the first panchromatic plates commercially available, the precursor of the modern panchromatic plates and films. Prior to that time the available photographic materials, with the exception of a few slightly green-sensitive orthochromatic materials, were sensitive only to violet and blue light. With such emulsions it was impossible to make photographic reproductions of colored objects in their true relative brightnesses as seen by the eye; but the panchromatic plate, being sensitive to the entire visible spectrum, made it possible to achieve for the first time true tonal rendering of a variously colored object.

By careful study of the absorption characteristics of dyes that could be incorporated in thin sheets of gelatin, Dr. Mees was able to develop a very complete series of light filters useful for a variety of purposes in the photographic art. These have been manufactured continuously during the past quarter of a century according to the standards that he originally established, and the filters are well known throughout the photographic world, having become almost reference standards for many purposes.

During his connection with Wratten and Wainwright, Ltd., Dr. Mees also developed a series of highly efficient safelights for the illumination of photographic darkrooms.

It was during this period that he began the first systematic investigation of the resolving power of photographic materials. It is well known that one of the required characteristics of motion picture photographic materials is a sufficiently high resolving power so that fine detail may be satisfactorily reproduced even when the tiny picture on the film is projected upon the silver screen, in many cases under a magnification of 200 or 300 diameters.

In 1912 Dr. Mees was invited by Mr. George Eastman to come to the United States to organize and direct a research laboratory for the Eastman Kodak Company. At about that time Gaumont Frères, a French organization engaged in making motion pictures, attempted to commercialize a three-color additive projection process for the production of colored motion pictures, and the Eastman Kodak Company acquired the American rights to the process. The process involved the making of a set of three color-separation negatives, and, obviously, such a set of color-separation negatives can be made only with film that is sensitive to all wavelengths of the visible spectrum. At that time no motion picture film of the panchromatic type was commercially available, and the Gaumont concern attempted to produce their panchromatic film by bathing the ordinary blue-sensitive product in a suitable dye solution. The result was far from satisfactory, since the sensitivity was not particularly high nor was the uniformity good. Dr. Mees, collaborating with other emulsion makers of the Eastman Kodak Company, therefore set to work upon the problem of producing a panchromatic motion picture film, and in 1914 a very satisfactory material of that type, having excellent sensitivity to all colors of the visible spectrum and a sensitivity sufficiently high for practical purposes, was produced at Kodak Park. The Gaumont process did not succeed commercially, but not because of lack of a satisfactory photographic material. This panchromatic motion picture film was the first of its kind commercially available, and was the immediate forerunner of the modern panchromatic motion picture film on which practically all motion picture negatives are made today.

Since that time he has continued his work very actively in the development of new and improved photographic materials, particularly of the panchromatic and dye-sensitized types. Under his direction

tremendous strides have been made in the manufacture and use of sensitizing dyes capable of extending sensitivity of the photographic material to wavelengths far into the infrared. His series of spectroscopic plates sensitized to various regions all the way from the ultraviolet to the extreme infrared have been of enormous value, particularly in the fields of spectroscopy and astronomy, and one of the infrared-sensitive materials in the form of motion picture film is of considerable value to the motion picture industry for obtaining special effects.

Thus far the developments mentioned have been very largely the purely personal accomplishments of Dr. Mees, the results of work that he himself planned and directly supervised, and in many cases did with his own hands. During the past twenty-four years he has directed the activities of a great research laboratory, the technical staff of which has increased from the small beginning of a few specialists, to a large group consisting at present of some four hundred men, engaged in investigation and developmental work in almost every field of photography and in other closely allied sciences. Dr. Mees' directorship of the laboratories has been by no means a passive one, but, on the other hand, has been most vigorous and aggressive. His unbounded enthusiasm, his vivid imagination, and his uncanny ability to suggest the most fruitful experiments to perform have been a constant source of inspiration and encouragement to the members of his staff. His preëminent fairness to those working under him, his kindliness, and his humanity have endeared him to the hearts of his associates.

The accomplishments of the Kodak Research Laboratories are very largely the accomplishments of Dr. Mees. While he has been successful as an individual research worker, we feel that his great success and his great contribution lie in the ability and sagacity he has shown as director of this research organization. It is therefore fitting that we should recount at this time some of the developments of the laboratories that must be recognized in large measure as part of his achievements.

In the twenty-four years during which the laboratories have been functioning, they have published some six hundred scientific communications in which the results of their researches have been made available to the public, and many of which have been of direct value and importance to the motion picture industry.

Among the important scientific accomplishments of the laboratories

are: the development of the theory of tone reproduction, upon which depends a truthful tonal representation of the object photographed; a complete investigation of the nature of photographic gelatin and its effect in enhancing the sensitivity of photographic materials; many studies upon the nature of the latent photographic image, upon the theory of development, and upon the methods of measurement of sensitivity and other photographic characteristics.

During the World War the research laboratories of the Eastman Kodak Company were engaged, under the direction of Dr. Mees, in many problems of military importance. A number of specialized plates and many filters for specific purposes were developed, and the United States School of Aerial Photography was established at Kodak Park, in which civilian instruction was organized by Dr. Mees and his colleagues.

In 1918, in addition to continuing as Director of Research, Dr. Mees was made Director of Development of the Eastman Kodak Company, and in 1923 became a member of the Board of Directors of the Company.

After the war, work was started in the laboratories upon the development of a process of amateur cinematography, which was carried through successfully and placed upon the market by the Eastman Kodak Company in 1923. The growth and importance of the industry that has grown up around the 16-mm. motion picture film and equipment are well known to this Society and need no further emphasis.

Following this, the subject of amateur color cinematography was taken up, and in 1928 a process of direct color cinematography, known as Kodacolor, was announced and introduced commercially. Work upon color photography was continued in the Laboratories, and further progress was made with the result that a new and improved process for amateur cinematography, Kodachrome, was perfected and introduced in 1934.

Dr. Mees is the author of many books on photography, and a list of his scientific communications dealing with various aspects of photographic science would be too long to mention in detail at this time.

His achievements in the field of photographic art and science have been recognized upon many occasions, as witness the numerous awards that have been given him. Among these we may mention the Henderson Award for photographic research in 1907; the silver medal of the Royal Society of Arts in 1908 for a paper on color photog-

raphy; the Progress Medal of the Royal Photographic Society in 1913 for research contributing to the advance of photography, this being the highest award of that Society; the John Scott Medal and Award of the City of Philadelphia for research in the fundamentals of photography in 1921; the Janssen Medal of the Société Française de Photographie in 1924; the Hurter and Driffield Medal of the Royal Photographic Society in 1924 for the memorial lecture of that year.

Amid prolonged applause, Dr. Mees received the Progress Medal from President Tasker, who addressed him in the following words:

"Dr. Mees, not through any right of my own, but as a servant of the Society, I am honored to add to the honors given to you by other Societies, this Medal, which the Society of Motion Picture Engineers confers upon you this evening for your outstanding work in this field."

In response, Dr. Mees spoke as follows:

"Mr. President, Dr. Jones, Members of the Society: I am greatly honored by the presentation of the Progress Medal of the Society of Motion Picture Engineers and am deeply touched by the account that my colleague, Dr. Jones, gave of my work.

"It is particularly gratifying that the account of my work should be presented to the Society by Dr. Jones, who has been associated with me for twenty-three years in our Laboratory and who has himself taken part in much of the work of which he spoke. Indeed, the results of the work on the theory of tone reproduction, which has been one of our major problems, should be credited to Dr. Jones himself. Most of the work that has been mentioned has been done to a great extent by my colleagues, with such assistance as I could give them.

"When I started in 1901 to do photographic research, I had a perfectly clear picture in front of me of what I wanted to do. I was interested in photography, practical photography, taking pictures with a very primitive camera. Incidentally, I sold my stamp collection to buy that camera, so you can see how young I was. I was learning to be a professional scientific man, and it irked me very much that not only had I no knowledge of the science of photography but I could not find any clear information upon the subject. The books available left great gaps in the structure of the subject. Much that was published was obviously incorrect, and much more was simply insufficient.

"Dr. Sheppard and I were friends then, as we are friends still; colleagues then, as we are colleagues still; and we decided that we should like to develop a coherent science of photography. We took up the science of photography as a subject of study while still undergraduates, and after two years of initial work, concentrated upon the problem as our post-graduate subject in preparation for the doctorate degree at the University of London. When the work had been done and our theses were published, I had to look about for a means of making a living, and there was no way of making a living then by continuing the study of the pure science of photography. In order to apply the work that I had done, I went into industry and started to make photographic plates. But when Mr. Eastman gave me the chance to come to Rochester and the promise that when I came I might have a research laboratory that would work upon the science of photography, I seized the opportunity. I was able to persuade Dr. Sheppard, Dr. Jones, and several other colleagues who are still with me to join me so that we might attack the problems of photography.

"A great many of the 600-odd scientific communications from our Research Laboratory deal strictly with the technical science of photography, so that today, as a result partly of our own work and partly of that of others, I can say that we now have a coherent, definite science of photography in which there are no large gaps. There is yet much work to be done, but the greater part of the skeleton of the science of photography has been laid down and the early work on fundamentals has held its place. That is a source of great satisfaction to me and to those who have worked with me.

"I often think that I have the best job in the world. There isn't any better fun in the world than having a laboratory where you can do what you want to do and where you can get results in the field in which you are interested. I have some self-sacrificing colleagues—Mr. Sulzer, who is here tonight, has been my colleague ever since I came to the Kodak Company. He and my other associates in the company do all the hard work while I have a good time. I am looking forward to the future with the belief that I can continue to have a good time in the same way. I hope that we shall be able to fill in some more of the gaps in our knowledge, to make some better materials than we have now, to do things that we can not do now. Especially, I feel that in the future we should make photography the true representation of the glorious, colored world in which we

live. The time has come when we should represent colors in photography as colors and not as 'a correct tone reproduction' of what the colors would be like if we could not see them. That little job will probably keep us busy, happy, and very much occupied in the future."

As a requirement of the regulations pertaining to the Progress Award, the list of previous medalists of the Society is to be published annually in the JOURNAL. As this is only the second time this Award has been given, only one previous medalist can be mentioned, *viz.*, Dr. Edward C. Wente, who received the Progress Medal at the Convention of the Society at Washington, October, 1935.

As Dr. Mees concluded, President Tasker addressed the Society in the following words:

"At this time it is my pleasure to introduce to you a man whom I have admired for many years. Earlier in the evening I had the opportunity of speaking to Mr. Aylesworth for a few minutes and asked him about his present work with the National Broadcasting Company. I also asked him what he was doing before he joined that Company.

"In reply he told me that he had been Managing Director of the National Electric Light Companies, and described a little of the work of those companies, the magnitude of which astonished me. I asked him whether he had ever had a small job, and I must inform you that with a big man's characteristic modesty and simplicity, he replied, 'I still have.'

"Mr. Aylesworth, it is a real pleasure to introduce you to this Society, particularly as you have now become one of us by devoting all your time to the motion picture industry, whereas before we have had to share you with the broadcasting industry.

"Ladies and Gentlemen, I present Merlin H. Aylesworth, Chairman of the Board of Radio Keith Orpheum, and formerly President of the National Broadcasting Company."

THE RELATION OF RADIO BROADCASTING TO MOTION PICTURES AND THE THEATER

MERLIN H. AYLESWORTH

I have made so many speeches during the last twenty years without any apparent results except a complete change in my voice due

to hoarseness, that I felt it was time to swear off on behalf of both listeners and myself. But last month when approached by your Banquet Committee, whose job it is to find some speaker who promises not to talk too long or too seriously, I had a deep conviction that I would like to pay tribute to the technical profession in the motion picture industry.

In this highly emotional, sometimes jittery, field of activity in which producers, associate producers, directors, associate directors, supervisors, artists, and often executives, rush madly about, in the supreme effort to produce a picture that will entertain and sustain the motion picture habit of the fickle public—there is always that quiet but effective balance of the technical organization.

You men who represent the great background of achievement in this business look upon this scene of mad activity with calm eyes, and remind one of the men in the line of a football team who make way for the fellow who carries the ball and obtains most of the glory.

I find the same true in radio broadcasting. I can give you one simple illustration—simple, I say, from the standpoint of the engineer, but entirely marvelous to one like myself, who, although totally ignorant of the technical side of any business, is highly appreciative of the results.

The date had been set by the landlord, Mr. Rockefeller, when the NBC studios in the RCA Building in Radio City would be completed and the rent would start. I was sufficiently familiar with the efficiency of the Rockefeller organization to know that on that date the vast studios of NBC would be ready. As you know, radio broadcasting is a continuous performance and it was essential that the broadcasting at 711 Fifth Avenue, the NBC Building, should be switched to the new NBC in Radio City without interruption.

Those who had charge of the selling of business, the programs, the music, and the general conduct of the broadcasting, continued to operate at 711 Fifth Avenue without giving much thought to the great change that was about to take place. The engineering force continued to function efficiently and to all intents and purposes had their hands full.

Late in the afternoon of November 10, 1933, Mr. O. B. Hanson, Chief Engineer, visited my office with the quiet warning that my office in the new quarters would be ready for me the next morning at 9 o'clock. He said my telephone equipment was all installed, the

dialing system for auditions was working excellently, and all the mechanical equipment necessary for my convenience in listening to programs and conducting the business was in good order. Looking sternly at Mr. Hanson I explained that the mechanical equipment for my office, and even the furniture, was unimportant compared to the general technical equipment for the studios and the actual operation of the radio programs. Mr. Hanson replied that they had naturally taken care of my office last, assuming it to be of the least importance. So, during the night between November 10th and November 11th the great change took place, and in all fairness I must say that it was due almost entirely to the efficient supervision and fine working organization of the NBC technical staff.

Now, in broadcasting we have a highly emotional as well as weird show business that must function to the second. Yet in all my years of activity in radio broadcasting I have never known a time when the engineers were not well ahead of the operation, and without any trumpets or flags waving in their behalf carrying on at the head of the parade.

The engineer never becomes a maintenance man. He is constantly looking into the future, just as those in sound broadcasting today are looking with fear and confusion at the laboratory progress of television. On the other hand, the engineer welcomes advancement and progress and change in the art, and is always meeting it rather than wondering in the background what will happen next to destroy his peaceful day.

There can be no question that the very foundation of a great part of American industry rests in the hands of the engineer. I mean by that, the engineering field of activity, whether in pure science or in the practical adaptation of technical equipment in a working business, is the job of the engineer. He has done his job well. It would take me an hour to cover a small number of the great names in engineering, all closely identified with the development of our greatest industries, whether in the field of manufacturing, public utility service, radio, motion pictures, *etc.* You are discussing this week highly important problems in the development of the motion picture art. You will solve those problems and the new ones to follow. The technical position of the motion picture art is out in front in the parade of motion picture production.

As I look back to 1935 and 1936, I am impressed with the outstanding achievements of this basic industry, which vitally affects every

member of the family, both from the standpoint of entertainment and instruction, and which is worldwide in its significance as a human service. May I state a few facts of importance to the motion picture industry and the public:

In the years 1935 and 1936 there have been more outstanding, one might say great, pictures than in the entire history of the industry. The classics, the great stage plays, the great stories of fiction have been brought to the screen with almost perfect technic and artistic production. This is due in no small measure to the demand by religious, civic, educational organizations, and the general public for better pictures both from the moral standpoint and the selection of subject.

The motion picture industry quickly responded to this demand and today has established a machine of self-censorship that definitely controls the policies of motion picture production without in any way hampering or destroying the creative ability of those who produce and act in motion picture production. Many prophesied that this self-imposed censorship would bring about "Pollyanna" pictures, and would take the vitality out of motion picture production. These prophecies were entirely unjustified. Our self-imposed censorship has aided the creative genius of our producers, directors, and writers in seeking higher planes of public entertainment.

History shows that the mediocre performer on the stage saved himself by being risque. Perhaps that was not so bad, because the adult audience within the four walls of the theater could laugh without much embarrassment in the presence of their friends. The radio and the motion picture are quite different. The radio enters the homes of the people, and there is no reason in the world why any person, young or old, should be shocked or hurt by the bad taste of those who bring entertainment over the radio into the American home.

While it is true that people pay admission fees to the motion picture theater, and some argue that that is like purchasing a book, a magazine, or a newspaper, and therefore comes under the privilege of selection of what the person wants, that is not an answer that will satisfy. Aside from some great stories with well known titles, most of the titles are unrelated to the themes of the pictures, and call for general attendance. It is true that some fine pictures are produced that are more satisfactory for adults than for juveniles, and many great organizations have helped in pointing out these classifications of pictures, which, I believe, is in the interest of fine picture production.

It must be remembered that while all people like good entertainment in motion pictures, the tastes of people are quite different. Even in New York City pictures are played in the Radio City Music Hall that would not draw so well in many other theaters in New York, and many pictures shown in certain New York theaters would not draw well in the Music Hall.

In certain parts of our great country the Western type of picture is considered much more entertaining than other pictures which are called "highbrow" and simply have no appeal for certain audiences. That does not mean that the industry should make pictures to please all the people and never attempt to make pictures that appeal to lesser groups; nor does it mean that the grade of intelligence changes in different parts of the country. The attendance at motion picture theaters is one of habit and custom. People will always like what they like, and we can not compel the public to come to see anything that does not appeal to their fancy.

Although the great story or classic or stage play has a drawing power, we must frankly admit that ours is a business of great stars, who achieve popularity with the people who pay at the box-office. We now come to one of the most important problems confronting the motion picture industry. I refer to steadily increasing costs of production. I am not referring particularly to the price paid to artists, directors, agents, and the rest; but it is quite apparent that the production of a picture today, produced, directed, and acted by the same persons on the same lot will cost substantially more than it did three years ago. Whether the blame may be laid to the management, to increased taxation, to the persuasive powers of agents, or to the mad scramble for bigger and better things due to the vigorous competition or lack of coöperation among the production companies in this industry, is the question to be answered.

It must be remembered that this increased cost of motion pictures is accompanied by lower rates of admission in all parts of the country than existed a few years ago. It must be remembered also that in many theaters of the country people now receive two feature pictures, along with short subjects and newsreels, for a lesser price than they once paid for a single feature picture. So the exhibitor or theater manager has his problem as well.

While we are making much finer pictures than we did in the past we still make too many indifferent pictures. I do not mean that the so-called *B* pictures have deteriorated below the second-grade or

so-called "program pictures" of a few years ago. Nevertheless, there are indifferent pictures produced that should never be made or released and have no real drawing power and annoy the paying audience. However, the great companies, because of many contracts and large organizations, which seem essential to the business under its present policies of operation, are burdened by fixed charges that call for a steady production of pictures and a large program in the number of pictures regularly produced.

It is very easy to make statements of this sort and rather embarrassing not to be able to give the answer to the problem. However, all the forces engaged in this great industry of entertainment are giving careful consideration to these major problems confronting the motion picture and theater business.

The steadily increasing cost of production at Hollywood can be met only by real coöperation among the major producing companies in prohibiting the waste of man power and money. This can be accomplished, even in a business as competitive as ours, by the heads of the major motion picture producing companies realizing and putting into practice a plan of real coöperation which is bound to lessen the cost of production by the coördinated use of specialized man power in every department among the various studios.

I am not referring in any way to reductions in salaries of the producer, director, or artist, or any unit of labor or man power. It may be argued that it is not feasible to coördinate activities among competitors. Enough has been done along this line to show conclusively that it can and must be done.

Attendance is closely approaching the peak figure of 1929, when you engineers brought sound as well as sight to the motion picture industry. Yet in most instances the price of admission is lower than it was eight years ago, and in many cases two feature pictures are given for a price less than was paid for a fine picture eight years ago.

We have now returned to prosperity, and there is no reason why the public should not voluntarily pay an admission price commensurate with the service offered. The double feature arose out of competition and depression. Many independent theaters put on two feature second-runs in the hope of drawing from the theaters that had first-run pictures. The result was that the first-run theaters, except when unusual pictures were shown, followed the example of their brother exhibitors and also gave two feature pictures.

Motion picture attendance is a habit and public interest must be

sustained. The practice of giving one Grade *A* picture with a Grade *B* picture is like eating too much ice cream at one time; and when the public is fully informed, the theater industry will have no trouble in doing away with what I regard a wasteful, injurious practice that does not properly serve the public, who will pay to see good pictures and are entirely satisfied with one good feature picture, interesting shorts, and a newsreel.

The double-feature program was a child of the depression—cheap admission and quantity entertainment. Now with the return of good times and increased spending power, by demanding quality and not quantity entertainment, the public will give the answer to this problem.

The general situation calls for coöperation between the motion picture companies and the theaters, and, of course, the general public, which after all receives the service and pays for it.

Many exhibitors complain of the types of contracts offered by the major companies. I am very happy to say that consideration is being given by individual motion picture companies and theater groups to more satisfactory contract arrangements. Naturally, there can be no standardization of contracts, and each motion picture company will necessarily proceed independently to treat with the exhibitors in the sale of pictures. I am sure that the coming year will bring forth the treatment that this problem requires and while the answer may not suit everybody, certainly the great majority of exhibitors will know that the motion picture companies have their interest at heart as well as their own.

I think it is simply marvelous and beyond understanding, how the great motion picture companies are able to produce so many fine pictures for public enjoyment. As you know, this is a business of twenty-four hours a day of activity, short lives for stars, and with such high-speed action that the casualties, the physical and mental breakdown, are beyond those of any other business with which I am familiar.

Much excitement and discussion has taken place recently due to the so-called competitive features of radio broadcasting with the theater and motion pictures. A good many exhibitors feel that radio broadcasting is responsible for keeping people at home. Many at the motion picture studios feel that motion picture artists should not appear on the radio.

I have always believed that the radio helps the motion picture and

the theater, and that the theater and the motion picture help the radio. Although radio broadcasting is now at its all-time high in drawing power for entertainment, both on the air and at the end of the receiving set, I believe it can be safely stated that a larger percentage of the population is attending the motion picture theaters than ever before.

It is true that these forms of entertainment should coöperate more closely; that only the motion picture stars who have radio personalities should appear on the air; and that working arrangements should be made at Hollywood so that there will not be interference between motion picture production and radio broadcasting. The radio broadcaster feels that the form of entertainment he offers, with the hit tunes from the motion pictures and the best of the stars as performers, is a definite exploitation in favor of the theater and the motion picture. These people should become acquainted and work together.

The entertainment industry is now faced with the development of television, which will be with us in a short time. I, for one, believe that the motion picture industry should work with those who are developing television so that when the history is written, the motion picture, the theater, and television will work for each other and enhance the public interest in all three mediums of entertainment.

Human beings are not so constituted that they will stay home all the time. If all the food in the world were crammed into pills and capsules, and all the entertainment came out of one box, people would still leave home for outside entertainment and a change from domestic habits. People go to motion pictures to get away from the actualities of life and people leave home (no matter how contented or happy) to get a change. Thus do we maintain happiness and contentment.

Just as Amos 'n' Andy created a national slogan that has had a very great and important effect upon the habits of our people: "Brush your teeth twice a day; see your dentist twice a year"—so should the radio broadcasters help develop the slogan for the motion picture and the theater: "Take your family to the motion picture theater twice a week."

THE LUMIÈRE CINEMATOGRAPH*

LOUIS LUMIÈRE**

Summary.—*A historical account of the development of the cinematograph camera and projector. Work on the apparatus was begun in 1894, and a private demonstration given in March, 1895, at Paris. The first public showing at which admission was charged took place in the Grand Café on the Boulevard des Capucines, Paris, on December 28, 1895. Motion pictures were also projected upon a screen approximately 80 × 100 feet in the Galerie des Machines at the Paris Exposition grounds in 1898, using a projection distance of more than 600 feet. The paper contains an illustrated description of the apparatus.*

When the Edison Kinetoscope appeared in Paris in 1894 in a shop on the boulevards, there were many who thought, after having peered into the eyepiece of this ingenious device, that the projection of the moving images, which were produced then for only one spectator at a time, would be of considerable interest. However, the continuous motion of the film in the Kinetoscope permitted the eye to perceive each of the elementary images during only a very short time ($^1/_{6000}$ second), and this feeble illumination, which necessitated examining the images in direct light, without interposing any diffusing surface, could not pass sufficient light for good projection. Moreover, the sharpness suffered considerably because of the motion of the elementary images, even during the very short time they were illuminated.

My brother and I decided to investigate the problem, and I soon succeeded in making a device in which the film was kept stationary, for a time corresponding to two-thirds of the total time, each time an elementary image appeared exactly on the lens axis. The device allowed the frequency of 16 images per second which I had previously established, and an illumination time of $^1/_{25}$ second per image, which is more than is needed for projection. This device consisted of a sliding block (Fig. 1) driven with a reciprocating vertical motion by means of a triangular eccentric, which stopped the motion of the block com-

* Requested and recommended for publication by the Historical Committee.

** Neuilly, Paris, France.

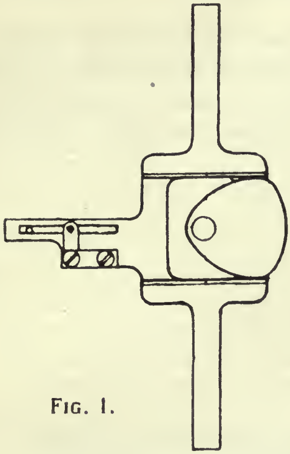


FIG. 1.

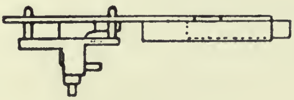


FIG. 2.

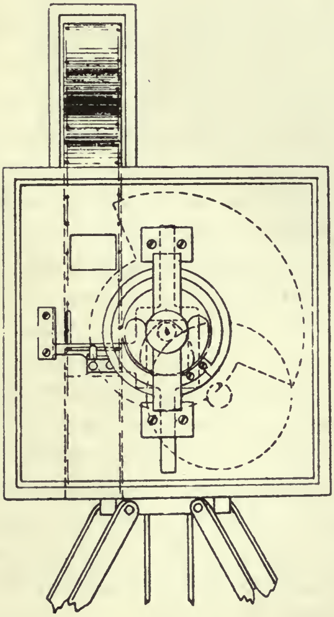


FIG. 3.

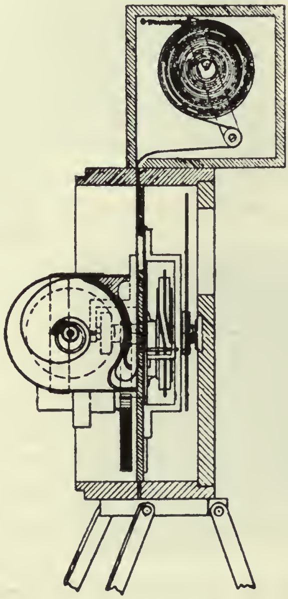


FIG. 4.

FIG. 1. Sliding block and triangular eccentric of pull-down device.
FIG. 2. Section through sliding block, showing mounting of pull-down pins.
FIG. 3. Front elevation of camera mechanism, showing arrangement of sliding block and pull-down pins.
FIG. 4. Side elevation of camera mechanism, showing helical cam controlling movement of pull-down pins.

pletely at the top and at the bottom of its travel during one-sixth of the total time. When the block was stationary, the tines or claws (Fig. 2) of a kind of fork located at the side sank into the perforations of the film, under the control of a helical cam (Figs. 3 and 4).

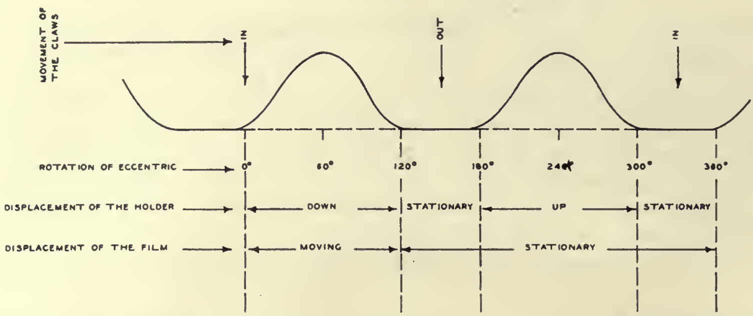


FIG. 5. Movements of film and various parts of pull-down mechanism during one exposure and pull-down cycle.

These pins described a rectangular path and carried the film along during their downward motion and left it motionless during their withdrawal, their upward course, and their sinking in. A pressure member, acting upon the film as a light brake, was sufficient to hold the film in perfect alignment with the gate behind which the image appeared, thus absorbing any play in the apparatus. The principle of the movement is shown in Fig. 5.

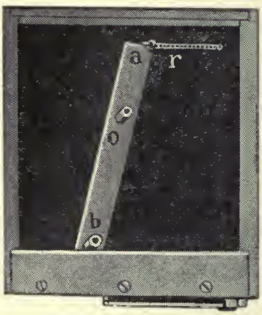


FIG. 6. Spring-lever in supply magazine to reduce effects of inertia of the film roll.

As I contemplated producing only short scenes, the length of the film was only 17 or 18 meters. I had not deemed it necessary to complicate the instrument by having a continuously running sprocket, the effects of the inertia of the small roll of film containing the images being deadened by a spring-lever (Fig. 6).

I shall not undertake to write the history of the motion picture industry; and without going back to Zoëtropes, Phenakistoscopes, *etc.*, I shall cite only the work of the astronomer Janssen, of Muybridge. and especially of Marey of the Institute, of Demeny, and of Reynaud, who at times carried out remarkable

analyses of motion; although none of the instruments of these men was able to achieve the animation of more than about 30 images, the projection of which involved much difficulty.

The first outfit I developed was made in 1894 in our factory at Lyons, according to my drawings and under my supervision, by our chief mechanic, Mr. Moisson. The first images I succeeded in obtaining were printed upon the photographic paper we were manufacturing at the time. Later, we obtained base film from the New York Celluloid Co. which we coated with sensitive emulsion in our machines, and made into perforated rolls.

The film described above had only two circular holes per image

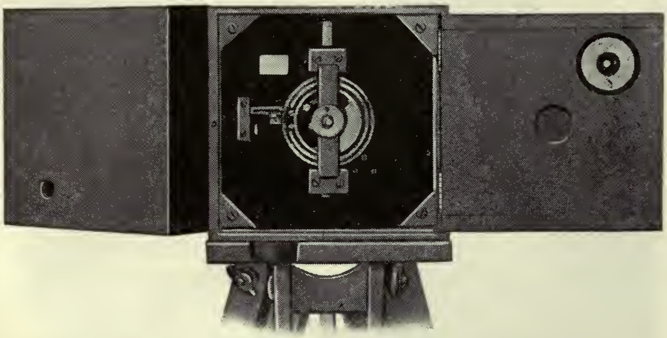


FIG. 7. Front view of camera with shutter removed.

and assured unusual steadiness in projection. I demonstrated the outfit, patented in February, 1895, during the course of a lecture at the Société d'Encouragement pour l'Industrie Nationale, in Paris, in March, 1895. At the time, I had only one film, which showed the employees leaving the Lumière factory—an easy subject, since I had simply to set up my camera in front of the factory gate at closing time.

This first demonstration was a great success. I met there Mr. Jules Carpentier, an engineer, member of the Scientific Academy, and a well known manufacturer of precision instruments, who immediately proposed to undertake to manufacture a series of Lumière cinematographs. I accepted the offer at once, and the Carpentier factory forthwith manufactured much of the apparatus, which could be used as cameras, projectors, and printers, since by providing a double-film

magazine, both the raw film and the negative could be run in together and printed. Figs. 7, 8, and 9 are illustrations of the equipment.

The results obtained were submitted to the Congress of the Photographic Society of France at Lyons, on July, 1895, and greeted with a tremendous acclaim. We decided to give public demonstrations with the equipment, and on December 28, 1895, opened a place in the

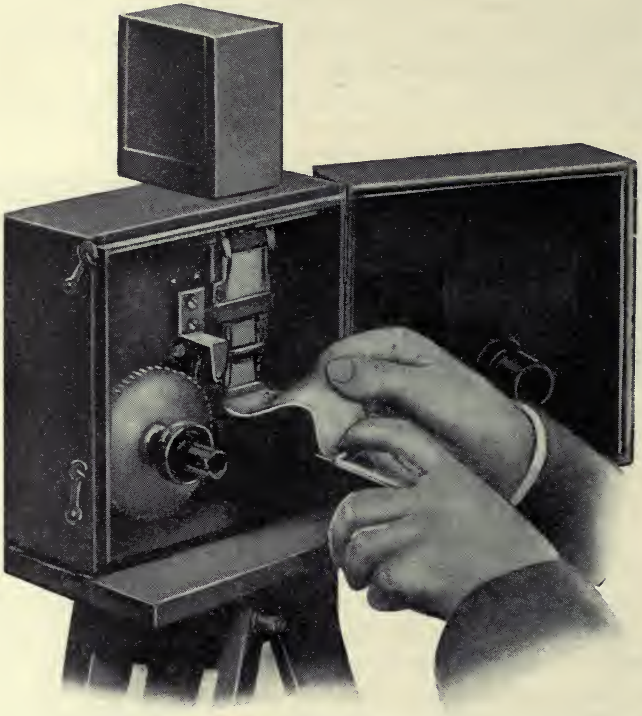


FIG. 8. Rear view of camera, showing method of threading film.

basement of the Grand Café, on the Boulevard des Capucines, Paris, where, for a small admission fee people could witness the projection of the following short films: *Men and Women Employees Leaving the Lumière Factory*, *Arrival of a Train at the Station of La Ciotat*, *The Baby's Lunch*, *The Sprinkler Sprinkled* (!), and *Boat Leaving the Harbor, etc.* The success of the showing when the existence of our place became known, was considerable, although no publicity was sought.

Thus, on that date, December 28, 1895, was really born the expression: "I have been to a movie."

In 1897, I announced a device (Fig. 10) utilizing as a condenser, a simple glass flask, as nearly spherical as possible, filled with water,

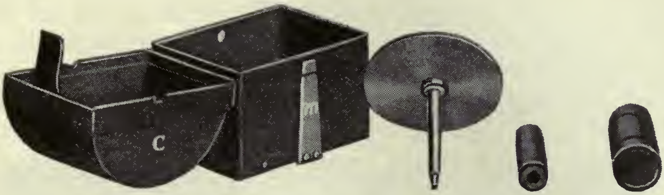


FIG. 9. Take-up magazine, unassembled.

and carrying in the upper part a small piece of pumice stone suspended by a thread in order to regulate the boiling of the water which occurred after prolonged use. The device thus formed a block system, since the concentration of the light-beam upon the film would cease

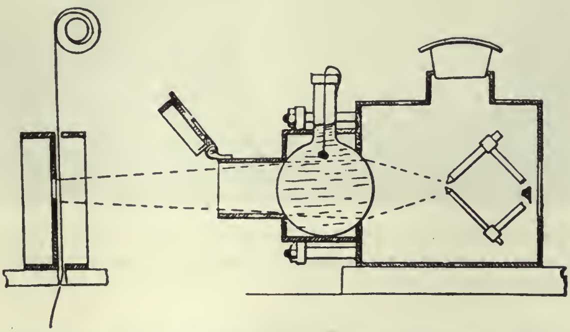


FIG. 10. Illuminating system of projector, with spherical flask acting as combination condenser and heat absorber.

in case the flask were broken. All our machines were furnished with these devices.

When the Paris Exhibition of 1900 was decided upon, in 1898, I was called to Paris by Mr. Picard, the general secretary, to whom I proposed the experiment of projecting greatly enlarged motion pictures at the Exhibition. With the small apparatus described above, I succeeded in projecting ordinary cinematograph images covering a screen 24 meters high and 30 meters wide, set up in the middle of the

Galerie des Machines, a huge building, 400 meters long by 114 meters wide, which had been constructed for the Exposition of 1889. Fig. 11 gives an idea of the size of the screen, set 200 meters from the projector. As a fabric for the screen I had selected a material that reflected, when wet, as much light as it transmitted, so that one could see the projected images from any position in the big hall. To moisten the screen on the day of the experiment required the assistance of the Paris Fire Brigade, since the screen was the height of a six-story building. The results were so remarkable that the screen was re-

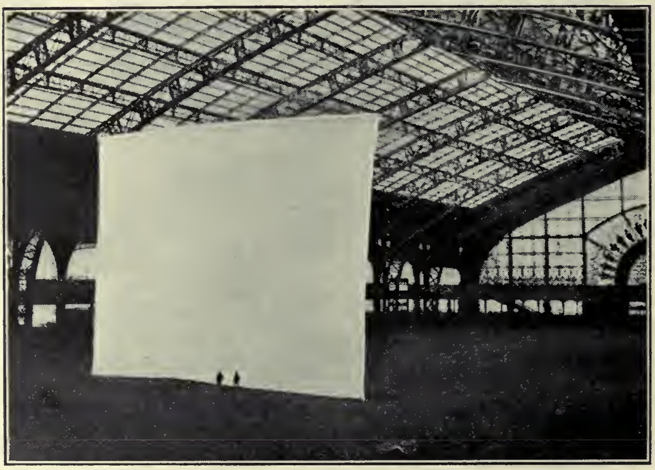


FIG. 11. Large screen 24 by 30 meters (79 × 98 feet) used for projection of motion pictures at Paris Exposition of 1900. Note figures of men at base of screen.

tained for the Exposition of 1900. Unfortunately, the Galerie des Machines was cut in the middle to make a circular hall more than 100 meters in diameter, and having a capacity of 25,000 seats. This forced me to reduce the dimensions of the screen to 16 meters high by 21 meters wide, and place it along a diameter of the hall. To avoid the difficulty of moistening the screen at the time of projection, the screen was kept immersed in a large rectangular tank of water, and each evening was raised out of the tank by a hand-winch under the cupola after removing the trap door that closed the tank during the day. I had to be satisfied with an arc of only 100 amperes, which, however, was sufficient because of the optical instruments used. The

demonstrations occurred each evening, without trouble, throughout the Exposition.

To obtain better definition in the images projected upon so large a screen, I had a camera built, with the collaboration of Mr. Carpentier, capable of producing images, 4.5 by 6 cm., having perfect definition, as shown in Fig. 12, which was taken on the opening day of the Exposition of 1900. Unfortunately, the camera was not finished in time to be used for the more ambitious programs we had planned, so we kept to the original small films. Since at Lyons we were unfavorably situated to undertake the production of longer films, and since we were more interested in our laboratory investigations, we abandoned the project in 1905.

FIG. 12. Print from film taken on opening day of Paris Exposition of 1900 in Lumière camera using wide film (4.5 × 6 cm. frame).

Every one knows how tremendously the motion picture projector has been developed, especially through the impetus and improvements that are due to a great extent to the efforts of American engineers and industry.

Louis Lumière

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SCIENCE AND THE MUSICIAN*

HOWARD HANSON**

Summary.—*A brief discussion of the attitude of the musician toward the recent development of electrical and other methods of reproducing sound. After alluding to the advances made in improving the quality of reproduction, the value of recording equipment to the musical student is referred to, followed by a brief discussion of the economic disturbances produced in the musical field by the scientific innovations. The paper discusses the subject with regard to both radio broadcasting and sound motion pictures.*

In choosing the subject, *Science and the Musician,* I realize that I am somewhat in the position of the high-school student who, as valedictorian of her class, sought about for a subject that would be sufficiently inclusive for the things she wished to say and finally chose the subject, "The Universe." As a matter of fact, I have chosen this subject in order that I may have some freedom to talk to you on various aspects of a relationship that is proving increasingly important. It would be presumptuous of me as a practical musician and a layman in the field of science to discuss with you technical aspects of matters of which you, yourselves, are authorities. I shall rather confine my subject to the aspects of science that have a practical bearing upon the musician and his art.

The musician looks at science with an attitude that is an admixture of equally compounded parts of respect on the one hand, not a little awe, and a certain amount of suspicion. A musician can have nothing but respect for the serious attitude that the scientist, particularly the scientist of the last fifteen years, has displayed toward his art. Though the scientist himself would be the first to admit that the efforts in sound reproduction are not yet perfect, the progress in the fidelity of recording in its various aspects has been little short of remarkable. Whether we are speaking of the field of the radio, recording sound upon film, or of the phonograph, there has been

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* Received October 12, 1936; presented at the Fall, 1936, Meeting at Rochester, N. Y.

** *Director,* Eastman School of Music, University of Rochester, Rochester, N. Y.

an expansion of the range of recording that has given to tone quality a remarkable similarity to the natural sounds of the instruments. As a musician it might not be amiss for me to hazard the opinion that perhaps the greatest work to be done lies in the field of intensity rather than quality. Whereas the reproduction of sound frequencies with their various partials has approached the point of perfection, the relation of amplitudes in recording is far from that achieved in the concert hall. Perhaps a consideration of relative levels in the correct interpretation of a symphonic composition might solve the problem more quickly than an attempt to reproduce accurate imitations of intensities achieved in concert performance. I have, for example, frequently watched the engineer in a broadcasting station, controlling the initial output of energy, so interfere with the interpretation of the conductor through his manipulation of the dials as to frustrate almost completely a diminuendo or a crescendo of vital importance in the satisfactory interpretation of the passage.

I should prefer, however, to pass over these technical matters, and speak rather of the artistic and economic effects of scientific development upon the progress of musical art. In the field of education it seems to me that scientific progress has been very largely synonymous with musical progress. Certainly the radio, phonographic reproduction, and, perhaps, to a lesser extent, the sound picture have brought to the average person an experience with music that would have been utterly impossible twenty years ago. I realize, of course, that many persons listen to music through defective or poor radio sets or through inadequate phonographs, which do not reproduce properly the sounds that the modern radio sending station or the modern phonograph disk make possible. Regardless of these handicaps, however, it seems obvious to anyone that today even on the most isolated farm it is possible to hear a great amount of first-class music well performed. I realize, again, that there are many musicians who have the point of view that the radio programs of our country contain too large a proportion of meretricious material and too small a portion of what is worth the listening time of the auditor. But, even admitting some justification in that point of view, it is possible to point to hundreds—perhaps thousands—of hours of music each year over the air by great orchestras, great chamber music ensembles, great opera companies, and great artists. Nor do I have a great deal of sympathy with those who feel that the radio should be under the stern and immediate direction of the federal government.

From what I have seen of broadcasting both in Germany and in England, it would seem to me that there is much to be said in favor of the American system; and that there is a good deal of truth in the philosophy that a country can not pull itself up by its own educational bootstraps; that it is perhaps better to have the culture of a country attain its own level through the gradual growth of a desire for better things.

Nor have the broadcasting companies as such been particularly remiss in their duties toward the American public. They have on many occasions shown themselves progressive in spirit and distinctly friendly to new artistic concepts and to the development of contemporary as well as classical music.

I should say that on the whole the use of the phonograph has been much less successful. Due perhaps to an innate conservatism, many of the recording companies have found it advisable to "play safe" to such a degree as practically to frustrate their own contribution to musical life. As a result, we find great gaps in the recorded literature of the world. This is particularly true in the field both of contemporary music and of education, where the tendency to record only music of undoubtedly proved popularity has carried with it the corollary of the neglect of a vast amount of other music both of contemporary and ancient times, the recording of which would be invaluable both to the music lover and to the music student.

On the other hand, the development of what we might call amateur recording is proving of enormous value. We have at the Eastman School, for example, a fairly adequate recording apparatus which, although it does not have the fidelity of the best professional equipment, nevertheless is entirely practicable for our purpose. Through this apparatus it is possible for us to allow the student instrumentalist or singer to record his or her performance and then to sit back and take an objective point of view toward the result of his endeavor. In the same way it is possible for a student composer to hear his own orchestral work performed, after which he may take away the recordings of the performance for repeated hearing. Inasmuch as a cardinal principle in teaching composition should, in my opinion, be that of providing opportunity to hear one's own work in sound, it can easily be seen how invaluable such recordings can be for the young composer.

The field of the sound film is, I believe, still in its infancy, perhaps not so much from the technical standpoint, but rather from the standpoint of the material to which this technical equipment is

devoted. That it is possible to give satisfactory performances of operas, ballets, or even of symphonic works through the medium of the sound-film can not, I believe, be seriously questioned. I recall with pleasure a German film taken several years ago in which the recording of a symphony orchestra playing a standard symphonic work was accompanied by intimate shots of the various sections of the orchestra. I can imagine no way more effective in making intelligible to the lay audience the structure and composition of a symphonic orchestra than such a method.

Viewed, therefore, primarily from the abstract standpoint of the contribution to the art of music, it would seem to me that the gifts of science have been most beneficial. That they will ever replace the actual physical presence of an ensemble or of an individual I very much doubt; that they will contribute largely to the understanding and enjoyment of great music I am convinced.

When we come to the economic situation, however, we face a turbulent and disturbed condition of affairs. I am perfectly cognizant of the fact that invention habitually disturbs economics and that science can not stop in its progress for fear of economic or social consequences. On the other hand, I do feel that it is not beyond the privilege of many thinking citizens to ponder upon the results of scientific innovations, and to use the modern inventions in a way, that will assist rather than retard human progress. The turbulent condition of the field of music has arisen largely through the rather sudden and highly satisfactory technical developments in the field of the motion picture and of the radio. The institution of the sound film had as one of its initial economic results the putting out of work of thousands of musicians engaged as instrumentalists in the various theaters of the country. This did not affect only the large theaters, many of which frequently engaged orchestras of practically full symphonic strength, but reached down into the smaller theaters which had ensembles too small to be dignified by the name of orchestras. In the smaller theaters the mechanical accompaniment of the picture is in many cases more satisfactory than the small and frequently ineffective orchestras that the theater was able to afford. In such instances the result of science was artistically beneficial and economically shattering. In the case of the large theater it was frequently harmful both from an artistic standpoint and from the economic standpoint. In cases where science replaced a poor musician with a mechanical product that was superior I have little

to criticize. In cases where science replaced a competent musician with a mechanical product not so good, the results seem to be harmful rather than helpful. There are some evidences that this condition may eventually right itself.

In the field of broadcasting there is equal danger, though, due to the apparent progressive point of view of the major broadcasting systems, the dangers are somewhat obviated. The use of huge broadcasting combines, in which one orchestra playing in one city ministers at the same time to hundreds of thousands of listeners through subsidiary broadcasting stations, might make possible, if not kept in constant check, a centralization of art that might be distinctly disadvantageous. As a matter of fact, such centralization is confronting America with a real problem at the present time. The extreme of mechanization would be to create sound records of one orchestra, which would then be mechanically reproduced and broadcast through all the stations of the country. In this way music could be for all time recorded, and after the last musician had passed out of existence the production of music would reach its ultimate state of economic perfection and the utmost extreme of artistic sterility. That such a condition might come about is technically possible, but that our people would be willing to allow themselves to be ministered to forever by artistic robots is hardly probable.

At the same time there is one other question that is definitely pressing. I refer to the economic support of music in this country in those cases where the organization to be supported is of sufficient size and excellence to be an artistic asset and an economic liability. Few listeners who "tune in" the New York Philharmonic Orchestra every Sunday afternoon throughout the symphonic season, and a good many nights through the summer season, have any conception of the financial difficulties that confront those charged with the maintenance of such an organization. It seems to be financially impossible for a great orchestra composed of the finest artists available to pay for itself through charging admission to those who come to its concert hall to listen. Perhaps a way may be found, but it is yet to be discovered. In the meantime, however, the artists who form this ensemble must be paid. They are, as individuals, professionals in the highest sense of the word. They are men of talent, who have devoted long years, much labor, and much expense to their training.

It is as obvious that they should be paid suitable salaries as it is proper that members of any other useful profession be so rewarded.

This places the responsibility upon the shoulders of those who feel that music is an important part of American life, and who would feel it a great loss if organizations such as our great symphony orchestras should go out of existence. It is customary, therefore, for all organizations, including our own in Rochester, to organize drives for funds for their support. In this cause many voluntary contributors give what they are able, not in return for tickets to concerts, but rather to subscribe to an inevitable deficit, the failure to meet which would mean the extinction of the organization.

Viewed from our American way of doing things, this may seem right and proper, but the fact remains that it places organizations that are not commercial in their conception upon a definitely unstable economic basis. At the same time hundreds of thousands of persons all over the country are listening to this music provided at great cost by a small group of individuals, and are listening to it at the cost of the few cents for electrical power to run their radios and a few additional cents for the occasional visits of the repair man. I have no feeling that music as such should be foisted upon the American people. I feel equally keenly, however, that those who listen to it should in all fairness pay for it. It seems to me, in other words, that there is much to be said in favor of the European system of a direct tax upon radios, the returns from the tax to be used solely for subsidizing the organizations that can not exist without financial support.

I might conclude my remarks by a brief summary. The gifts of science to music have been invaluable, and the scientific contribution to the development and progress of musical art has been, and will continue to be, far reaching. At the same time, however, the intrusion of science into the arts has radically changed the economic set-up. It is perhaps unwise, and perhaps even impossible, for the economics of music to proceed in the future on the same basis as in the past. It is, therefore, perhaps not unwise that, while paying our respects to science, we, as musicians, urge the sympathetic consideration of our brothers in working out new plans made necessary by the very progress that has changed the fundamental conditions. Music must forever be a living art. It must be produced by creative minds living not only in the past but in the present. It must be reproduced through the flesh and blood of living artists. Without the coöperation of these two forces both art and science will suffer defeat. Through their coöperation we may bring into being a new golden age of creative artistic thought.

DISCUSSION

MR. CRABTREE: There have been demonstrations in which the sound was amplified to such an extent that the energy put forth far exceeded that which emanates from the average symphony orchestra. Have you heard such demonstrations? If so, what was your reaction to such music? Was it favorable? Or do you feel that such an amount of power is never necessary?

DR. HANSON: My feeling was not so much concerned with the level of the reproduction as with the fact that frequently the beauty of a musical composition is destroyed either by the inability, or perhaps carelessness, of the operator in maintaining either the original level of the music, or by automatic changes in the level which frustrate the purpose of the music.

I believe that one way of overcoming such difficulties would be for the technicians who are directly responsible for the broadcasting to get enough musical training to be able to follow an orchestral score, so that they will not, through musical inexperience unintentionally frustrate the purpose of the composer.

DR. GOLDSMITH: In radio broadcasting, as in sound recording and reproduction, limitations of the available or permissible volume range are encountered at practically every step. That is, it appears impracticable, in the present state of our knowledge, to reproduce the dynamic range of music economically and with satisfaction to all concerned in the home.

In the case of radio broadcasting, the amplifying equipment, telephone lines, and transmitters all impose certain limitations. The minimum volume that they can adequately handle is controlled in some measure by the electrical noise-level inherent in each portion of the system. The maximum volume that can be handled depends upon the nature of the equipment, economic limitations, and the possibility of introducing "cross-talk" from a program-carrying telephone line into neighboring telephone lines.

Even if transmission of the broadcast music had full dynamic range, serious difficulties would be encountered in the homes of the listeners. Radio receiving sets, built within economic limits, are not capable in general of reproducing the full dynamic range of music without distortion of tonal quality. It is not worth trading correctness of tonal reproduction for mere volume of noise.

Further, the softest volume of music that can be enjoyed in the home must still be louder than the noise level. Since many homes are located in noisy neighborhoods, and since the home audience is not always completely silent, the lower limit to musical volume of reproduction in the home is fairly high. On the other hand, the average home is not adequately sound-insulated from neighboring homes, particularly during the summer months when windows are customarily wide open. The upper limit of musical volume in reproduction in the home must be such as not unduly to annoy the neighbors. In summary, the permissible volumes of music in the home lie between the neighborhood noise and the neighborhood feud—and this constitutes a definite limitation of dynamic range.

It is not intended by these comments to take a pessimistic attitude. If expansion of the dynamic range of musical reproduction in the home will not yield to an explosive frontal attack, it may nevertheless yield in time to a slower evolutionary process. Step by step the various limitations in radio transmission and reception can be improved, and ultimately whatever dynamic range is most desirable in the home will be attained. I happen personally to doubt that the full

symphonic orchestral range in the home is esthetically desirable—but whatever range may be found most acceptable to the public will doubtless ultimately be attained.

It would have been interesting to have had Dr. Hanson's viewpoint on electric musical instruments. Some of our finest musicians have studied certain of their capabilities. It is now possible to produce various tonal qualities synthetically by electrical means, to attain any desired dynamic range with such instruments, and (to a limited extent) to control even the "format" of the tones (that is, the mode of growth and decay of the otherwise sustained notes).

The impression might have been gained from Dr. Hanson's paper that radio broadcasting is free in the United States in the sense that the listeners do not pay for it. That is incorrect; the American broadcast listener pays for his radio entertainment through the direct exercise of his purchasing power. Statistically, the cost of radio entertainment is borne by almost infinitesimal additions to the sales prices of the important commodities advertised through the radio medium.

There is room for differences of opinion as to the desirability and probable effectiveness of the support of radio broadcasting in America through taxation of the listeners. Consideration of the cost of such tax collection, the possibility of wide evasion, the departure from established American ideas on such subjects, the difficulty of equitable and non-political distribution of thus collected funds, and the tacit program control thus involved are all markedly negative factors in relation to such a proposal. There is little in the history or traditions of the United States to justify a change from the present and effective system of broadcasting, so far as this country is concerned.

MR. CRABTREE: To get back to the theater, I should like Dr. Hanson to put a "yardstick" on the quality of the sound that we are getting there. You stated that the frequency and volume ranges were fairly satisfactory, but, of course, the sound does not have the auditory perspective peculiar to "flesh-and-blood" music. What is your reaction to such music—can you tolerate it?

DR. HANSON: The first question is very difficult to answer because it depends upon so many factors that do not remain, will not, and perhaps can not, remain constant. There is, in the first place, apparatus of varying qualities.

The best I have heard was in one of the sound recording laboratories in New York, where, I suppose, the work being done was perhaps as good as was done anywhere else. What I heard was simply splendid. Music of that kind comes almost as close to an ideal as anything I have been able to think of. Unfortunately, we do not generally listen to music in such ideal conditions. We listen to it through machines that are not so good, and in rooms that are not so well adapted to reproduction, and sometimes under other conditions that are far from ideal.

Being a musician I am perhaps a little more conscious of the *what* of music than I am of the *how*. I have a very tolerant ear. What I can not hear "in the flesh" I can imagine. If, for example, I hear a French horn that does not have all the mellowness that a good French horn would have "in the flesh," my ear is perfectly willing to accommodate, and add what is missing. But, if bad music is played, I can do nothing about it. My inner ear will not help if the music is bad even if it is given out over the best apparatus made by the greatest scientists.

I think that is the musician's point of view, as opposed to the scientist's. We are probably much less critical, as professional musicians, of sound reproductions

than you are as scientists. In fact, I am convinced of it. I have remarked to scientist friends of mine that certain reproductions were magnificent, and they told me they were terrible.

MR. FRANK: For many years the question of low-frequency response had been a bothersome one, particularly for manufacturers of equipment. Probably because some early radio receivers having greatly accentuated low-frequency response were put on the market, there seems to have been a continued demand ever since, by the public, for greater low-frequency response than occurs in original music. That seems wrong to me, theoretically. If the listeners do not like the arrangements, or the kinds of instruments used in the orchestras to which they listen, then it is for the conductors to make the changes, not those who record the sound or who manufacture the equipment. Nevertheless, it is the public that affords the manufacturers the possibility of staying in business, with the result that we can not attempt to educate the public too quickly as to what is correct.

The patrons and owners of the majority of theaters today are demanding of the reproducing systems low-frequency responses that are entirely out of proportion to the original recording. In the average home the "tone control" (which is provided more as a "sales argument" than anything else) is adjusted to attenuate the high frequencies as much as possible, perhaps because of interfering noises, or because the high frequencies seem shrill.

From an esthetic point of view, does the public desire, and is the trend of taste toward, more highly accentuated low-frequency response than the present music calls for, or is it a temporary situation and a matter of education, which sooner or later is going to be overcome?

DR. HANSON: Those are difficult questions, to which I would not presume to give the right answers. My opinion is that there are two answers. I have noticed frequently that ears seem in so many cases to be painfully sensitive to high frequencies. I do not know why I find people again and again objecting, never to cellos or violas, for example, but always to the piccolo, or the high B flat or C trumpet. I have always assumed, without having any scientific reasons for the assumption, that in many ears such high frequencies produce discomfort of some sort, which may be the reason why those persons prefer the low frequencies.

So far as taste is concerned, what you say is quite correct. I believe that there is a tendency for the listener to want what he calls "rich" sounds. When he speaks of "rich" sounds he does not mean sounds that are rich in high partials, but rather sounds that have their basic notes at low frequencies: he regards such sounds as "rich" and "luscious." If anyone can explain to me why certain vocal tones used, let us say, in broadcasting by certain types of vocalist, have a definitely overpowering fascination for a large proportion of the radio audience, I should go away from here feeling that my visit was a million times repaid.

SOME HAZARDOUS PROPERTIES OF MOTION PICTURE FILM*

A. H. NUCKOLLS AND A. F. MATSON**

Summary.—*The hazards in handling or storing cellulose nitrate motion picture film are due to the unusually low temperature of ignition of the film, the extremely rapid rate of combustion, and the possibility of its decomposing (exothermic) even in a restricted supply of air (oxygen), with the evolution of explosive and poisonous gases. Data and information in respect to these hazardous properties of cellulose nitrate film are given. The importance of complying with the regulations of the National Board of Fire Underwriters can not be overestimated in obtaining adequate provision for handling and storing film safely.*

Film having a cellulose acetate base was first submitted to the Laboratories about 20 years ago, and as the result of an extensive investigation, the acetate-base film in the form of ribbon for motion pictures was listed as slow-burning, the fire hazard being somewhat less than that of common newsprint paper in the same form and quantity. Data in respect to the hazardous properties of slow-burning cellulose acetate film are given, together with a brief description of tests conducted on slow-burning films at Underwriters' Laboratories.

Many cellulose nitrate film fires and explosions in the past involving loss of life and damage to property have been thoroughly investigated by underwriters and others in order to devise measures to control this hazard. Through the combined efforts of the National Board of Fire Underwriters, the National Fire Protection Association, and manufacturers of cellulose nitrate, regulations governing the handling and storage of inflammable film have been worked out and have been in use for many years. This paper will discuss some of the hazardous properties of cellulose nitrate film and also the cellulose acetate slow-burning type of film.

In handling and storing nitrocellulose, or, chemically speaking, cellulose nitrate, film, the danger is due to the unusually low temperature of ignition or decomposition of the film, its extremely rapid rate of combustion, and the fact that it can decompose (exothermic) even in a restricted supply of air or oxygen, with the evolution of explosive and poisonous gases.

*Presented at the Spring, 1936, Meeting at Chicago, Ill.

**Underwriters' Laboratories, Chicago, Ill.

Many combustible substances with which we are familiar, such as wood and paper, when heated rapidly do not ignite until a temperature in the neighborhood of 600° or 700°F is reached. Cellulose nitrate decomposes when exposed to temperatures in the neighborhood of 300°F. On prolonged exposure decomposition of nitrate film may occur at temperatures as low as 230°F.

The temperature of ordinary incandescent lights, steam pipes, as well as that of lighted cigarettes and matches, exceeds 300°F, and such sources of heat may therefore ignite the film. Hence in handling and storing cellulose nitrate film, it is of great importance not to have any portion of the film near steam pipes, incandescent lights, or any source of heat.

Everyone is familiar with the fact that the chemical reaction known as combustion is accompanied by the evolution of heat. The amount of heat developed by the combustion of a unit mass of a given substance is known as the heat of combustion. The heat of combustion of a given substance is always the same if the conditions of the chemical reaction are the same, regardless of whether the combustion takes place slowly, or rapidly, or occurs in air or in pure oxygen. The difference of temperature that is noticed between the slow and the rapid combustion of substances depends primarily upon the length of time during which the heat of combustion is evolved. In the absence of other factors affecting the result, we may regard the temperature as depending upon the quantity of heat evolved in unit time.

The heat of combustion of nitrocellulose is about the same as that of wood, being six to eight thousand Btu's per pound, but the *rate* of combustion of nitrocellulose is from twelve to eighteen times that of wood in the same form. It will be evident, therefore, that the temperature attained by the combustion of cellulose nitrate is extremely high as compared with that of other substances commonly met in practice. Film fires are therefore very difficult to control, and may cause considerable damage within a very short time.

Most of the products with which we are familiar are formed from their elements or elementary substances with evolution of heat, and therefore during decomposition absorb heat. Cellulose nitrate is formed from elementary substances with *absorption* of heat, and therefore upon decomposing into simpler compounds evolves heat so that the process after once starting tends to maintain and accelerate itself.

Under practical conditions the decomposition of cellulose nitrate

may or may not be accompanied by combustion, depending upon the conditions, particularly as to the air supply. When stored in vaults and other closed places where the supply of air is restricted, decomposition of large quantities of film may occur within a relatively short time.

When cellulose nitrate film burns freely in an excess of air the gases evolved are carbon dioxide, nitrogen, and water vapor, none of which are poisonous.

When cellulose nitrate film burns or decomposes (with or without production of flame) in a restricted supply of air, as would be the case in a closet or vault, carbon monoxide (CO), nitrogen dioxide (NO_2), and nitrogen tetroxide (N_2O_4) are evolved. Other gases such as hydrogen, methane, and traces or negligible amounts of hydrocyanic acid gas, and, in the case of undeveloped film, traces of hydrobromic acid are also evolved. Under ordinary room conditions 1 pound of cellulose nitrate film yields about 4 to 5 cu. ft. of these gases which, of course, expand as the temperature rises, according to the well known gas law. The proportions of carbon monoxide, oxides of nitrogen, and hydrogen evolved depend in a measure upon the conditions, but the poisonous oxides of nitrogen and carbon monoxide are always produced by the decomposition of nitrate film in dangerous quantity under conditions likely to be met in practice. When the decomposition of the film takes place under pressure, as may be the case in a closed vessel or vault not provided with vents, hydrogen gas is evolved in considerable quantity.

It will be noted that when carbon monoxide or when hydrogen gas is evolved under conditions where the supply of air is not sufficient to cause their immediate combustion, a potential explosion hazard is introduced, inasmuch as these gases may be ignited later when they reach a supply of air (oxygen).

It is generally believed that fire-extinguishing systems employing water serve only to extinguish or control film fires; but as a matter of fact, the application of water to decomposing film serves a double purpose, inasmuch as the water reacts chemically with the poisonous oxides of nitrogen, reducing them to nitric acid, which is soluble in water. In a well sprinklered room in which films are stored, the bulk of the poisonous oxides of nitrogen evolved by decomposition of the film would be chemically acted upon and dissolved by the water. Unfortunately, the poisonous carbon monoxide gas is only slightly soluble in water and can not be effectively removed by this means.

It is apparent from the foregoing considerations that when cellulose nitrate motion picture film is used, adequate provision should be made for its safe handling and storage, having in mind the low ignition and decomposition temperature of the film, its extremely rapid rate of combustion, and the possibility of its decomposing with the evolution of explosive and poisonous gases. The importance of complying with the regulations of the National Board can not be overestimated.

Film having a cellulose acetate base was first submitted to the Laboratories about twenty years ago; and as a result of an extensive investigation, acetate-base film in the form of ribbon for motion pictures was listed as slow-burning, the fire hazard being somewhat less than that of common newsprint paper in the same form and quantity. This type of film, however, did not come into general use immediately, probably on account of the superior qualities of the cellulose nitrate film for photographic purposes. Recently, however, the manufacturers of acetate film have succeeded in improving its qualities to a marked degree, and this type of film is now quite generally used, particularly in projectors of the nonprofessional or miniature type, which may be operated in public without a standard booth if the slow-burning acetate film is used.

The ignition temperature of cellulose acetate is between 700° and 800°F, as compared with about 300°F for cellulose nitrate. A temperature of about 500°F is required to produce decomposition of cellulose acetate film. In the neighborhood of this temperature the evolution of fumes in material quantity occurs.

The decomposition of cellulose acetate film, however, is not exothermic, as is the case with cellulose nitrate. In other words, the decomposition of cellulose acetate film once started does not continue except under conditions where there is an external source of heat. It will be noted that in the case of cellulose nitrate film the decomposition continues when once started, even in the absence of an external source of heat. This difference between the decomposition of cellulose nitrate film and that of cellulose acetate film is therefore of great importance from the fire and life hazard standpoint.

The cellulose acetate film continues to burn when once ignited if the supply of air is sufficient to support combustion freely. The combustion, however, will cease in a restricted supply of air. The rate of combustion of cellulose acetate film is relatively slow, and the amount of heat evolved is of a low order, being much less than that evolved by paper or wood.

Like all cellulose products, cellulose acetate during combustion or decomposition gives off irritating and suffocating fumes. Results of research tests conducted at Underwriters' Laboratories indicate that 1 pound of cellulose acetate yields about 1 cu. ft. of gas when heated in a closed vessel without excess of air. These gases include principally carbon dioxide, carbon monoxide, hydrogen, methane, alcohols, acetic acid, ketones, and aldehydes.

Under practical storage conditions the acetate film will, in case of fire, be subjected to combustion in a more or less restricted supply of air (oxygen). In this event the combustion will be accompanied by some decomposition. Under such conditions most of the hydrogen, methane, and carbon monoxide will undergo oxidation or combustion, but sufficient quantities of carbon monoxide (about 1 per cent) may be evolved to render the air surrounding the fire, particularly in a closed room, dangerous to breathe, as would be the case in the combustion of paper under similar conditions. The acetic acid fumes, aldehydes, and ketones are irritating and suffocating, but are not comparable in their poisonous effects to the deadly oxides of nitrogen evolved by the decomposition of nitrate film.

Perhaps the most important safety factor with reference to cellulose acetate film is its slow combustion, which can be stopped easily by applying water or by smothering the fire. It is therefore possible to provide measures readily for controlling film fires involving cellulose acetate. In small quantities, the film can be safely used for amusement purposes without special safeguards, but where large quantities of cellulose acetate film are to be stored, it would be advisable to provide a cabinet or vault, preferably of fireproof construction.

FIRE PREVENTION IN THE MOTION PICTURE INDUSTRY*

HENRY ANDERSON**

Summary.—*After pointing out briefly the functions of the Conservation Department of the Motion Picture Producers & Distributors of America, Inc., in relation to the fire hazards in the motion picture industry, a résumé is given showing the exceptional record of the industry with regard to film fires since 1928, despite the inflammable nature of the materials used by the industry.*

The various types of fire extinguishers and other fire fighting equipment in use are described and their most suitable applications explained. Methods of preventing and fighting fires in studios, laboratories, exchanges, and theaters are discussed at some length.

The subject of fire prevention in the motion picture industry is an extremely broad one. The motion picture industry embraces almost every known science, art, and profession, and the foremost developments in almost every branch of applied science. It likewise involves practically every known fire hazard and fire risk, and its fire fighting and fire prevention problems are exceedingly complex.

Fire prevention is of the utmost importance to the industry; probably of far greater importance than most of us in the industry appreciate. We do not, for example, realize how far-reaching the effects of a fire in a motion picture studio or laboratory may be.

A serious studio fire may curtail production for weeks or months. A minor fire in complicated laboratory apparatus may put the laboratory out of service for a long period of time. A fire seriously damaging the sound recording equipment may delay studio operations for months. A large motion picture corporation may through a serious studio fire find its entire financial structure impaired. Delay in completing pictures, failure to meet contracts, continuing high expenses due to contractual obligations, such as those with talent, and inroads of competitors, involve incalculable possibilities of loss. The jobs of thousands of persons may be imperiled by such a fire. A fire in an exchange means not only a loss to the distribu-

* Received October 15, 1936; presented at the Fall, 1936, Meeting at Rochester, N. Y.

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tor but may involve serious loss to exhibitors, due to inability to supply film on schedule. A fire in a theater may involve loss of life.

The amounts of film, our basic product, handled by the industry are enormous. Statistics could best be presented in astronomical units such as light years. The problem of fire prevention in our industry is increased because film is readily combustible. We are con-

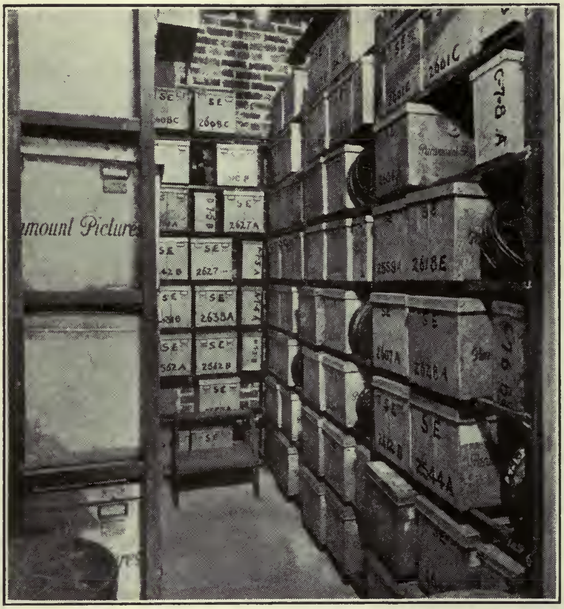

FIG. 1. Vault interior, Seattle (Wash.) exchange. Note that all films are in metal containers: large cans are I. C. C. containers; small cans are approved vault containers. Note the approved type of vapor-proof light. The sprinkler system is not visible in this picture. The ladder is of metal.

stantly confronted with this fact, and film must be surrounded by every reasonable safeguard, from the manufacturer's plant to its final disposition as scrap. We are further confronted with the fact that film is highly susceptible to damage by water and smoke.

Another problem confronting the fire prevention engineer is the proper protection of sound equipment. In sound equipment we may have a large investment, half a million dollars or more, concentrated at one point. This is the heart and nerve center of the studio.

Sound equipment is exceedingly delicate, complicated apparatus, and may be damaged as a result of fire to a degree far beyond that measured by the actual severity or intensity of the fire itself.

Fortunately we have in our own industry an outstanding demonstration of the fact that fires can be prevented and their results minimized by intelligent forethought, care, and planning. The fire loss record in our motion picture exchanges is, as far as can be determined, the lowest and best of any industry or any branch of any

FIG. 2. Inspection room, St. Louis (Mo.) exchange. Note the mesh screen over the radiators, sand pail, vapor-proof lights, sprinklers, metal window frames, metal chairs and tables, side-wall pilot lights, scrap film container. The room has two exits, one into the shipping room and another into an alley.

industry of any kind in the United States. This is no mere chance, but the result of definite concrete effort, and is an outstanding accomplishment. It has come about in the following manner:

Practically all the motion picture producers and distributors are members of the Motion Picture Producers and Distributors of America, Inc., popularly known as the Hays Organization. There are 376 exchanges joined in this Association out of a total number of 450 located throughout the United States and Canada. These ex-

changes represent a physical investment of many millions of dollars. Approximately 20,000 theaters are served through these exchanges, and it has been conservatively estimated that 30,000 miles of film are handled daily through these exchanges.

About 15 years ago, the Hays Organization established a department known as the Conservation Department, which supervises all matters relating to fire prevention in motion picture exchanges. It carries on a continuous fire prevention campaign. It makes periodic inspections of motion picture exchanges, and its recommendations are carried out to the letter.

In addition to inspections made directly by its Conservation De-

FIG. 3. Film shipping department, St. Louis (Mo.) exchange.

partment, the Hays Office appoints a Committee in each city composed of representatives of various distributing companies, which makes an inspection each month of each exchange in the City. The Committee is usually accompanied by an officer of the local fire department and the secretary of the Film Board of Trade. In this way we are sure that the inspection is unbiased. Exchange managers take pride in avoiding criticism by a Committee made up of their competitors. About 5000 such inspections are made each year, and the cumulative effect of all the inspections is bound to produce good

results. The inspection reports are sent to and followed through by the Hays Organization. During each inspection a fire drill is held; and, in addition, most of the exchanges hold fire drills on their own initiative once a week. Each year a trophy is awarded to the exchange showing the best record for housekeeping and fire prevention conditions.

In addition to the inspections made by the Hays Organization and the local committees, the home office of each distributing company requires a written monthly inspection report.

A printed instruction card, with a separate set of instructions for each operation is posted in each room of an exchange, giving detailed information as to handling film, the quantities of film permitted in each room, fire extinguishers required, how to handle fire, *etc.*

Activities such as these keep fire prevention foremost in the minds of exchange employees. Now let us see the result of this work:

1936.—No fires have occurred to date in exchanges of members.

1935.—Two inconsequential fires occurred in member film exchanges in the United States, with a total loss of $8. No film was involved in either case.

1934.—One fire, with a loss of $148.50, occurred in the inspection department of a member exchange in Dallas, Texas. It is reported that in some manner a parlor match had accidentally been dropped into a can of film prior to delivery to the exchange. The automatic sprinkler system functioned quickly and effectively. Seven inspectresses in the room left quietly and no injuries resulted.

1933.—No fires occurred in exchanges belonging to members of the Hays Organization.

1932.—Three fires occurred in member exchanges, the losses being, respectively, $25, $15, and $1. These all occurred in the office sections.

1931.—No fires in member exchanges.

1930.—One fire; loss $15; 600 ft. of film destroyed.

1929.—One fire; loss $1200, caused by defective concealed wiring in the advertising accessories sales department. No film was involved. (This section of an exchange contains posters and other advertising matter.)

1928.—One fire; loss, $25. This fire burned part of a reel of film as it was being rewound.

The record prior to 1928 is not available. Note the small number of fires in which film was involved; only three in nine years. The total monetary loss was less than $190. There could be no more

practical demonstration of the effectiveness of intelligent direction, control, and coöperation in fire prevention work.

The industry does not stop at the doors of its exchanges in active fire prevention. For example, every exchange is followed up by the Hays Organization as to its method of disposing of scrap film. The industry has tightened up on non-professional use of film, which at one time occurred freely in churches, schools, and institutions. The Conservation Department recently investigated four thousand schools, churches, orphanages, and penal and other institutions to determine the safety of their motion picture projection arrangements. About three thousands of these institutions were approved for the continued use of film, and this work alone brought about the installation of 360 standard fire resistive booths in institutions not properly equipped, all of which has greatly reduced the hazard to life and to property.

One of the constantly recurring problems with which the property owner or operator is confronted is to determine the type of fire extinguishing equipment best suited for any particular purpose. There is a great deal of misunderstanding and even misrepresentation with respect to various fire extinguishing devices, and the engineer should have some knowledge of this subject. Space will not permit going into the theory of fire and fire extinguishing in detail, but in brief, fire is oxidation with liberation of heat, and fires are extinguished either by excluding oxygen or by cooling the substance to a temperature below its burning point, or there may be a combination of the two methods.

We might ignite a piece of paper in a glass jar and then cover the top of the jar, excluding the air. The paper will stop burning as soon as the oxygen contained in the air in the glass has been exhausted. If we pour water upon burning paper the burning ceases, because we thus cool the paper to a temperature below its ignition point. However, it is not as simple as all that, for there are many modifications. For example, nitrocellulose film contains in itself the elements of combustion, and we can not extinguish burning film by excluding oxygen. We should, therefore, not look to an extinguisher that depends upon a smothering effect for extinguishing film fires. The only effective agent would be a liquid having sufficient cooling capacity to reduce the temperature of the burning film to below its ignition point. Water seems to be the one best all-around agent for that purpose.

In order to obtain a clearer picture of accepted fire fighting methods it is necessary to have a knowledge of the principal types of extinguisher in general use. They are as follows:

Soda-Acid.—This is the familiar $2^1/_2$-gallon brass tank equipped with a hose. It contains a solution of bicarbonate of soda in water and a container filled with sulfuric acid. When the extinguisher is inverted, the two mix, forming carbon dioxide gas which produces a pressure and forces the liquid through the hose. It has the same extinguishing effect as an equivalent amount of water, and is recommended for general use where water would be effective. The extinguisher is made in capacities up to 80 gallons.

Foam.—This type depends for its effectiveness upon applying to the burning material a blanket of foam containing bubbles of carbon dioxide, and is effective because of the smothering effect of the foam. It is effective particularly in gasoline and oil fires, but should not be used on electrical apparatus. Portable extinguishers are similar in appearance to the soda-acid type. Fixed equipment is often provided for gasoline and oil storage tanks.

Carbon Dioxide.—This type consists of a cylinder charged with carbon dioxide gas, and may be either portable or connected by piping to fixed outlets. It depends for its effectiveness upon displacing or diluting the air that would otherwise support combustion, thus smothering the fire. It is suitable for use upon ordinary combustible materials and inflammable liquids and for marine use. Fixed installations are made for use in confined spaces. Small rooms or compartments may be filled with the carbon dioxide gas, thus cutting off the oxygen supply. Some consideration must be given to the possible ill effects of the gas, inasmuch as carbon dioxide will not support life. To detect leakage the extinguishers should be tested by weighing at least annually.

Carbon Tetrachloride.—These are of the familiar hand-pump type, and are particularly adapted for electrical fires, as the liquid is nonconducting. They are suitable in certain special cases for use upon burning oils, but are not recommended for general use. In confined or unventilated spaces, precautions should be taken to avoid breathing the gases and vapors liberated when they are used on fires. The gases are also corrosive, which is of importance in connection with delicate electrical apparatus. The extinguishers should be tested at least annually by partly discharging and refilling.

Dry Chemical.—These employ an inert gas to discharge a dry

chemical in powder form through a hose. They are effective in oil fires, and may be used about electrical apparatus.

There are on the market a great number of other miscellaneous fire fighting devices, such as glass bombs, bottles filled with various liquids and tin cans filled with sand or powder, comparatively few of which have any real value except in special cases. Sand pails are often prescribed for motion picture booths by local fire departments. There would appear to be no possible conditions under which they might be effective in booth fires.

One important guide in the selection of the extinguisher is the label of the Underwriters' Laboratories. If so labeled, there is assurance that the device is reliable; but the mere labeling does not mean that the extinguisher may be used indiscriminately for every kind of fire. Each extinguisher must be selected for the purpose for which it is intended.

Recently some success has been had in controlling and extinguishing oil fires by means of a special spray nozzle, developed in England, using water at high pressure. The nozzle is so designed that it breaks up the stream of water into a very fine spray, which is ejected at high velocity. It is possible that further developments in the use of high-pressure sprays may be of value and importance to the motion picture industry. Water applied to fire under such conditions seems to be considerably more effective than when thrown from a sprinkler system, hose, or extinguisher.

Such a spray has a great cooling effect. The fine spray cools the surrounding atmosphere, and is most effective in preventing the spread of fire. It has also the property of washing out obnoxious fumes and gases given off by burning or decomposing nitrocellulose film or other material. One of the large sprinkler companies made some tests for the writer with these spray nozzles on burning film, and, as a result, it was felt that they merited further consideration and study. With the spray in operation a reel of motion picture film reasonably isolated can be completely consumed by fire with little, if any possibility that the fire will be communicated to nearby film or equipment, with the fumes reduced to a minimum and with the temperature of the room kept at a normal degree.

Burning oils afford a somewhat difficult problem. We do not have much success in extinguishing oil fires with water. Unfortunately, oil is lighter than water, and water from hose streams or sprinkler systems used on oil sinks to the bottom and may cause the

oil to rise and overflow. The spray method, however, depends for its effectiveness upon the fine globules of water penetrating the oil for a short distance and forming an emulsion of oil and water at the surface of the oil. This emulsion contains a sufficiently high percentage of moisture to be non-combustible, and there is thus formed a non-combustible blanket over the surface of the liquid. In addition, the water has a cooling effect, and the steam produced excludes oxygen.

An automatic sprinkler system is the best all-around fire fighting device. Automatic sprinklers have behind them a record of many years of effectiveness in fires of all kinds. Studios, laboratories, vaults, exchanges, and all rooms wherein film is handled and stored should be equipped with automatic sprinklers. The hazard to life is practically eliminated in sprinkled buildings. The spray from sprinklers has a great cooling effect, and washes out smoke and obnoxious gases given off by the burning materials. The requirements for maintenance are highly technical and space does not permit covering them here.

The construction and arrangement of vaults for storing film have been standardized. The principal features are a capacity limited to 750 cubic feet; walls and floor of 8 inches of brick, or 6 inches of concrete, or 12 inches of hollow tile; roof of 6 inches of reinforced concrete; fire doors on each side of wall; vents; automatic sprinkler system with baffles; and vertical rack partitions.

A motion picture exchange is well standardized as to fire prevention. The vaults are standard, and as a rule the sections where film is handled are of fire resistive construction and equipped with automatic sprinklers. The excellent fire record of exchanges has been discussed previously, and by the test of time and experience the fire hazards of exchanges have proved to be well controlled.

Laboratories are generally provided with standard automatic sprinkler systems, but few, if any, special fire extinguishing devices have been adopted by our industry in connection with our laboratories. Here is, I believe, a field for the installation of special devices at machines where film may accumulate, and constant effort should be exerted to keep down the amount of film outside the vaults to a minimum.

The laboratory should, in addition to an automatic sprinkler system, be provided with a standard equipment of fire extinguishers, $2^1/_2$-inch hose, small hand hose, and a complete fire-alarm system,

and the exit facilities should be adequate. There should be provided in laboratories, and, in fact, wherever film is handled in any great quantity, a supply of two or more gas-masks. These may be effective in reaching the seat of a fire and in rescue work. Persons should not be subjected to the fumes of burning film unless equipped with a mask. It may be interesting to know that until recently no tests had been made to determine the effectiveness of the canister type of mask in film fires. The U. S. Bureau of Mines has, however, made such tests, and has found that the Burrell-All-Service mask is safe for such use. The oxygen helmet is also effective, but is cumbersome to use.

The motion picture studio presents a serious problem to the fire prevention engineer. Automatic sprinklers face one of their most difficult tasks in the motion picture studio. The amazing effectiveness of automatic sprinklers has resulted from their operating almost immediately after the occurrence of fire, thus catching the fire in its incipient stage. Due to the great ceiling heights and the large areas found in studios there is very likely to be some delay between the occurrence of fire and the time when the temperature at the roof rises sufficiently to fuse the automatic sprinklers. The first few minutes of a fire are the most important ones. With the element of delay brought about by studio construction, the task of the automatic sprinkler is greatly increased.

In addition, inside the studios are platforms, decks, and enclosures, which form spaces that the water from the automatic sprinklers can not reach; so that although the automatic sprinkler is an entirely reliable device, we must realize that unless we are careful we may be expecting it to do something in the studio for which it was not originally intended.

Under studio conditions sprinkler systems should preferably be provided with what is known as central station valve alarm service, namely, devices attached to the sprinkler system that give an alarm immediately when the sprinklers begin to operate. The alarm should not only give aural warning in the studio itself, but should indicate the location of the fire, through an electrical system, in the central station of one of the fire alarm companies, which in turn would transmit the alarm to the fire department.

Fires have occurred in our own experience, the first knowledge of which came to those in the studio by the arrival of the fire department trucks at the gates of the studio, in answer to an alarm transmitted

by the sprinkler system. However, the fire department has always found that the fire was out or was under complete control of the automatic sprinklers.

We had a fire at our Hollywood studio that completely destroyed the first sound stage constructed on the day before our first sound picture was to be made. Unfortunately, although a sprinkler system was being installed, it had not yet been completed and put into service. The building had been designed by sound engineers, but apparently, no regard whatever had been given to the fire risk, for all the sound insulating materials were highly combustible. Strangely enough it was found possible to reconstruct the stage of non-combustible materials that proved to be more satisfactory than the combustible sound-proofing materials previously used.

As a result of this fire, we made a complete study of our entire fire fighting apparatus at the studio, tore out all the old sprinkler systems and hydrants, and put in a new and complete modern system at a cost of almost half a million dollars. The first fire after the installation was completed occurred on a Saturday afternoon when the studio was closed. Before the fire was discovered the sprinkler system had completely extinguished it and the studio management stated that they felt that the entire cost of the installation had been justified on the basis of its effectiveness in this one fire alone.

In addition to installing a complete sprinkler system of the conventional kind, we provided a complete system of outside fire hydrants from which any point in the studio could be reached by at least two lines of $2^1/_2$-inch hose, using not more than 150 feet of hose from each hydrant. The large hose was supplemented by a smaller complete equipment of $1^1/_2$-inch hose, which can be handled by one person, and it is now possible for a night watchman to reach any point in the studio single-handed with one of these small hose streams.

One of the great dangers during our fire arose from embers falling upon the roofs of adjoining studio buildings, where several small fires were started. We did not have enough ladders to get up to the roofs promptly, and it was difficult to get hose or extinguishers up. We have therefore provided permanent ladders giving access to every roof of the studios, and have, in addition, installed $1^1/_2$-inch hose at the roof level, so that it is now possible to send men to the roofs to extinguish promptly any falling firebrands.

The studio lot, with its outside sets, also presents a serious problem. Do what we may, congestion on the lot is sometimes unavoidable,

and a fire on the lot under such conditions is an extremely difficult one to handle, for the heat given out by rapidly burning material is so intense that not only does the fire spread rapidly, but it becomes difficult to approach near enough to fight it effectively. With ordinary hose streams it might either be impossible to approach close enough to the fire to fight it, or intervening sets and obstructions might prevent directing the water effectively to the seat of the fire.

It occurred to the writer that what we needed was a super-hose stream; one of such force that it would demolish an ordinary set,

FIG. 4. A $1^1/_2$-inch nozzle in operation on a set.

making it less likely to become part of a conflagration, and the stream could immediately reach the actual seat of the fire. Two or three such nozzles have been provided. They are $1^1/_2$ inches in diameter and have a tremendous force behind them. Nothing except a most substantial structure can stand up against them. The stream has a horizontal reach of almost 200 feet, a vertical reach of 80 or 90 feet, and will throw 5000 pounds, or $2^1/_2$ tons, of water a minute. A stream of this type is of value in the case of fires in sets inside the stages.

At the same time that we installed our fire protection equipment, we installed a motorized fire department, consisting of experienced retired firemen, and in addition formed a brigade among the employees, the men being taken from the mechanical force.

The regular firemen perform one of their most valuable functions as fire inspectors. They constantly patrol the studio, and carry with them report forms upon which they record any defective conditions they may see. The original record is served upon the head of the department where the condition exists; a copy is sent to the mechanical office, and a copy is retained by the fireman. The copy filed at the mechanical office serves as a follow-up. The head of the department must turn in the copy given to him, indicating that the condition has been corrected, before his record is cleared. This procedure can be successful only if the fire department is backed up unfailingly by the studio management.

Fire in and about sound recording equipment presents an acute problem. Such equipment is highly susceptible to damage by fire, smoke, and water. In addition, it is extremely expensive, a value of several hundred thousand dollars being involved in a single comparatively small unit. There is, too, the element of delay in production until the unit can be replaced. Our own company has spent a great deal of time and effort in making tests to determine the best fire fighting practices and the best fire equipment to use.

Of first importance is to have a supply of tarpaulins on hand which can be thrown over equipment not immediately involved in the fire but which might be damaged by water.

Several pairs of asbestos gloves are kept near the sound equipment, to be used for beating out small fires or handling hot wiring or other parts at time of fire. We have experimented with various fire extinguishers, and after considering all factors have adopted the carbon dioxide type. This type discharges a large volume of carbon dioxide gas at extremely low temperature. Carbon dioxide will not sustain combustion and, therefore, serves to blanket the fire out. Distilled water in a pump type of extinguisher, or an extinguisher using a cartridge filled with gas at high pressure, may be used as a second line of defense.

However, prevention of fires is far better than extinguishing them, and engineers engaged in the design, construction, and maintenance of sound equipment should give the utmost consideration to prevention of fire. Non-combustible materials and insulation should be selected whenever it is within reason to do so. Capacity of conductors should be adequate. Avoid too large values in any one unit. Design should call for segregation in rooms of fire resistive construction, divided into comparatively small sections and equipped with

every modern fire detecting and fire extinguishing device. The room should also be water-proofed not only against leakage but against rising water.

Fire protection is a special art and it is asking too much to expect the motion picture engineer to be thoroughly informed or to keep abreast of new developments in it. The advice of well qualified and informed fire prevention engineers should be sought before the design is commenced, and contact should be maintained throughout.

In the motion picture theater, safety to life is of first importance. Wherever persons congregate in large numbers there is always present the possibility of loss of life, often from even the most inconsequential causes. Fire is one of these causes, and one of the most dreaded. In well operated theaters, fire protection and fire prevention are given the consideration they deserve. Daily inspections are made. Adequate exit facilities are provided. The stage is provided with an asbestos curtain, stage skylight, and automatic sprinkler system. The projection room is of fire resistive construction, ports are provided with automatic shutters, and doors are self-closing. Adequate mechanical ventilation is provided. Fire resistive film cabinets are installed.

The theaters operated by the industry are today confronted with rapidly rising costs of public liability insurance. In some instances rates have increased ten times or more during the past two or three years. This is partly due to the racketeering type of claim and to increasing claim consciousness, but, on the other hand, a great many claims arise from actual physical defects in the theater and from improper operation of the theater. The balcony, particularly, with its irregular stairways and inadequate lighting, both overhead and at specific points, contributes to a large percentage of the accidents.

The average aisle light, as constructed and installed, is practically useless. It throws a concentrated light upon a single spot, and makes the general condition worse rather than better. There is need for an adjustable type of aisle light that will throw a diffused light and generally illuminate the aisle or steps.

In general, the overhead illumination in motion picture threaters is insufficient from a safety standpoint. There is a field for the engineer to design overhead and special illumination that will not throw light upon the screen or glare in the patrons' eyes, but will nevertheless provide safe illumination for seating and passage of patrons. It might be possible to establish the minimum degree of

illumination at the floor level adequate for safety of the patrons.

The SMPE can perform an important service in the prevention of fire in projection rooms, and in preventing damage if such fires occur. One way in which to accomplish this is to improve the machines and equipment constantly, with the object of making them safer, and sound equipment should be enclosed and so installed as to be less likely to be damaged by a trifling fire or by smoke or water.

Although the Fire Underwriters have issued regulations covering the construction of booths, and they and various city authorities have made regulations covering the installation of extinguishers, no one has yet covered the subject of just how a fire in a projection room should be handled. If the SMPE could formulate such a code, it would be of great value and assistance to the industry. Likewise, a code is needed regarding the procedure of fighting fires in sound equipment. The subject is certainly important enough, and recommendations made by the SMPE would carry much greater prestige than those originating outside the industry. The SMPE constitutes, in certain technical problems, the one best contact between the motion picture industry and outside associations engaged in fire protection work. There is a great opportunity for important constructive work in this field.

STABILITY OF MOTION PICTURE FILMS AS DETERMINED BY ACCELERATED AGING*

J. R. HILL** AND C. G. WEBER†

Summary.—*The stability of the cellulose acetate or safety type of film was studied in comparison with the cellulose nitrate or theater type of motion picture film. The study consisted in determining the resistance of films to various accelerated aging treatments, including oven-aging in dry air, aging in steam chest, and oven-aging at high humidity. The most satisfactory aging test was the oven-aging test commonly employed to determine the stability of paper. Effects of oven-aging upon the different types of film were determined by measuring the changes in physical and chemical properties after aging. In all tests, the acetate type showed much greater resistance to deterioration than did the nitrate film. The results indicate that the acetate film is a very stable material, being comparable to permanent-record paper in its resistance to accelerated aging. The nitrate type of film was found to be comparatively unstable.*

The physical properties discussed in the paper include (1) folding endurance, and (2) loss of weight. Of the chemical properties, the following are discussed: (1) acidity, (2) stability test of nitrate film, (3) copper number, (4) viscosity, and (5) the effects of aging upon gelatin emulsion. A foreword by John G. Bradley, of the Division of Motion Pictures and Sound Recordings, National Archives, introduces the paper.

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* Received October 12, 1936; presented at the Fall, 1936, Meeting at Rochester, N. Y.

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This study was made with the assistance of a fund granted by the Carnegie Corporation to the National Research Council and a fund allotted by the National Archives, and with the advice of the following Committee appointed by the National Research Council: Robert C. Binkley, American Council of Learned Societies and Social Science Research Council; John G. Bradley, National Archives; E. K. Carver, Eastman Kodak Company; H. T. Cowling, National Archives, representing the Society of Motion Picture Engineers; V. B. Sease, Dupont Film Manufacturing Company; F. W. Willard, National Research Council; and H. M. Lydenberg, New York Public Library, *Chairman*. The Committee on Preservation of Film, of the SMPE, also coöperated.

FOREWORD

JOHN G. BRADLEY*

For some time past, many institutions—libraries in particular—have faced the problem of record storage in terms of space, cost, and stability. Among other subjects seriously considered with a view to a solution is the problem of photographically transferring records to a film base by what is commonly known as microphotography.

Custodians of records have accumulated experience in this field, but most of them hesitate to adopt a definite policy until more is known about the stability of film bases. The National Archives is especially interested owing to the great volume of Government records under its jurisdiction, duplicates of which in many cases are not available. The interest was increased when the Division of Motion Pictures and Sound Recordings was set up and efforts were made to preserve such material.

As a result, the National Archives transferred money and personnel to the National Bureau of Standards with the understanding that the study then in progress on cellulose acetate film would be broadened to cover also cellulose nitrate film. Under this arrangement the work has moved forward rapidly and with gratifying results. The National Archives acknowledges the coöperation of the National Bureau of Standards and other participants in this work for their helpful contributions.

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I. INTRODUCTION

Motion picture films on a cellulose acetate base are being used as an inexpensive and convenient means of reproducing important records and for making original records for historical and other educational purposes. The interest in films for such purposes has become widespread because of the great saving in library space and the greater availability of material afforded the research worker.

At the request of the American Library Association and other organizations concerned with the preservation of important records, an investigation of the chemical and physical properties of cellulose acetate films, relative to their stability, was undertaken. This work is a natural extension of the studies previously made on the preservation of records on paper. The American Library Association is interested in the stability of cellulose acetate film and information concerning the best practice with respect to its storage and use. The National Archives is interested in all problems involved in the preservation and use of both nitrate and acetate films because both types will be stored and used there. By coördinating the two projects, more rapid progress has been attained than would have been otherwise possible.

II. MOTION PICTURE FILMS STUDIED

A motion picture film comprises a base of transparent sheeting, usually approximately 0.0055 inch in thickness, coated with an emulsion in the form of a thin layer of gelatin containing a silver compound extremely sensitive to the action of light. There are two types of film base in use, both being transparent cellulose esters: cellulose nitrate and cellulose acetate.

Cellulose nitrate sheeting is the base in the ordinary theater type of motion picture film. It is essentially a mixture of cellulose nitrate and camphor, and is highly combustible. It ignites at low temperature and burns very rapidly, giving off large volumes of oxides of nitrogen which are poisonous. Cellulose nitrate is relatively unstable in any form. The base of the safety type of film contains cellulose acetate. This material is comparatively stable chemically, is not highly inflammable, and burns no more rapidly than ordinary paper. The samples used in this study were furnished by the three principal domestic manufacturers of motion picture films and were said to be representative of current commercial products.

III. DESCRIPTION OF TESTS

The stability of the films was studied by determining the changes in their properties under accelerated aging. Various aging treatments were tried, consisting in (*1*) oven-aging at 100°C in dry air, a method of aging that had been found suitable for paper;[1,2] (*2*) oven-aging with moisture provided by an open vessel of water in the oven; (*3*) heating in a steam chest at 99°C; and (*4*) oven-aging at 100°C with the film inside stoppered bottles containing saturated potassium sulfate solution, providing a relative humidity of 95 per cent.

Both physical and chemical tests were used to measure the effects of accelerated aging. Any change in chemical properties should be reflected in the physical properties, and it is desirable to obtain a correlation between them. The physical property most sensitive to deterioration appears to be the flexibility, which can be measured by a folding test. The loss in weight on heating was also recorded. The chemical testing comprised determinations for: acetyl content and copper number on acetate film; flash or explosion temperature, and stability at 134.5°C for nitrate film; and acidity as *p*H and relative viscosity of acetone solutions for both types of film.

The determination of acetyl content, undertaken to find whether the aging of acetate film resulted in loss of acetic acid, was discarded for the more direct determination of free acidity developed in the film, as change in *p*H. The available methods of testing for acetyl content were not sufficiently sensitive to detect changes due to aging. Likewise, for nitrate film, the flash-point test was found to be unsatisfactory as a measure of stability, and the stability test at 134.5°C, used by the Ordnance Department of the United States Army for testing guncottons, was substituted. This latter test was found to be applicable to the testing of nitrate film as the time of reaction was affected sharply both by changes due to artificial aging, and by those due to natural aging. All aging tests were made on samples of whole film, that is, film with the emulsion. Samples were taken from new films that had been exposed and processed by the manufacturers. These films gave a negative test for residual hypo.

IV. PHYSICAL PROPERTIES

(*1*) *Folding Endurance.*—In studying the effect of accelerated aging upon the folding endurance, two types of folding testers were tried: the M.I.T. folding tester used for paper, and the Pfund type of tester which is used by the Dupont Film Manufacturing Corporation

for films. The Pfund type was found to be somewhat more reliable as to reproducibility of results than the M. I. T. type. Difficulty was encountered in the use of the latter because a slight distortion of the film on aging caused edge cracks when folded over the jaw edges. The Pfund type folds without tension, forming a small loop not in contact with any metal edge. It appears to give a satisfactory measure of flexibility, and, although hand-operated, the results are quite reproducible.

For measurements of folding endurance, test strips of film were cut 15 mm. wide and about 75 mm. long, and aged at constant temperature for the required length of time. After aging, the strips were conditioned under the standard conditions of 65 per cent relative humidity and temperature of 70°F before testing. Control strips were in all instances conditioned and tested under the same conditions. A 24-hour conditioning period was used in all cases, as both types of film were found to reach practically constant weight within that time.

The results of ordinary oven-aging at 100 ± 2°C on the folding endurance of cellulose acetate and cellulose nitrate film are shown in Fig. 1. The curves show average values for three brands each of acetate film and nitrate film. Both curves start with about the same slope, and show a retention of between 80 and 85 per cent of the original folding endurance after 24 hours of aging. On continued heating, the acetate film changed very slowly in folding endurance. After 30 days the average retention was about 67 per cent, and after 150 days (not shown on curve) it was still about 50 per cent of the original value. For the nitrate films, the loss in folding endurance continued at about the initial rate until all folding endurance was lost. After 10 days' heating, the folding endurance was zero for 2 brands, and the third became zero after a few days of additional heating.

Moisture vapor in the oven practically doubled the loss in folding endurance for both types of film for a 72-hour period. It was not continued for longer periods because using open vessels of water in the oven resulted in extreme and uncontrollable changes in relative humidity. In the steam chest, nitrate film went to pieces rapidly; while in the case of the acetate, the base became opaque and separated from the emulsion without loss of folding endurance. Upon heating this base in the oven, it again became transparent. The most consistent results, with respect to effects upon folding endurance, were obtained with oven-aging in dry air.

(*2*) *Loss of Weight.*—Oven-aging film was found to be accompanied

by a loss of weight that was not regained upon reconditioning. This fact aids in understanding some of the results of oven-aging upon folding endurance. Weighed samples of film were aged for different

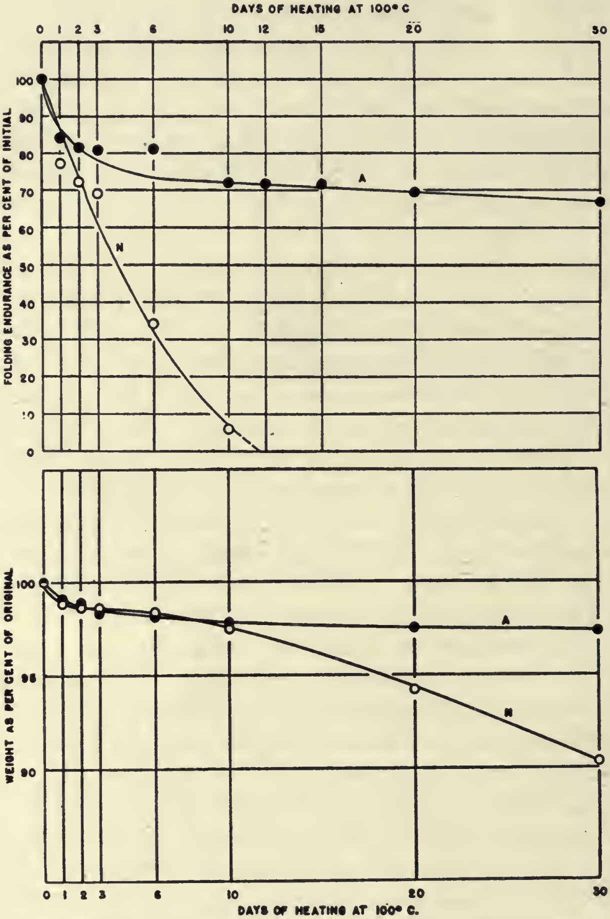

FIG. 1. (*Upper*) Effect of oven-aging upon flexibility of cellulose acetate and cellulose nitrate motion picture films.

FIG. 2. (*Lower*) Loss of weight during oven-aging of cellulose acetate and cellulose nitrate motion picture films.

periods and weighed again after conditioning for 24 hours. The final weights calculated as percentages of the original weights are shown upon the curves of Fig. 2. The curves are similar for both

types of film up to a period of about 6 days, but thereafter the loss of weight of acetate film is slight, while the nitrate continues to lose at a comparatively rapid and constant rate. These curves are similar in

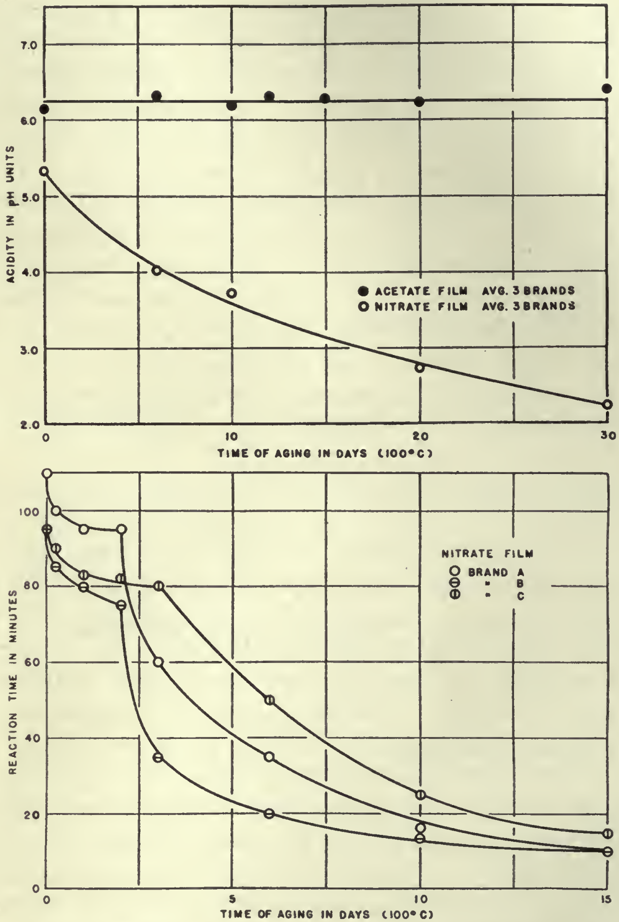

FIG. 3. (*Upper*) Effects of oven-aging upon *p*H of cellulose acetate and cellulose nitrate motion picture films.
FIG. 4. (*Lower*) Effects of oven-aging of cellulose nitrate film upon its stability at 134.5°C.

several respects to those for folding endurance. In each instance, the initial change was probably due to the loss of volatile substances, such as residual solvents and camphor in the case of nitrate film. Upon

further aging, the slow change in the acetate film indicates greater stability.

V. CHEMICAL PROPERTIES

(*1*) *Acidity* (*pH*).—Decomposition of cellulosic materials is usually accompanied by an increase in their acidity; hence measurements of *p*H were made to determine whether aging was accompanied by any increase in acidity. For this test, 1-gram samples of film were weighed and, after aging the base of the specimen, dissolved in 100 cc. of acetone containing 10 per cent by volume of water.[3] The *p*H of the solution was measured with a glass electrode. The results are shown in Fig. 3, in which the *p*H of the solution is plotted against the time of aging. The curve for acetate film shows some fluctuations, but no significant changes for any period of aging up to 30 days. On the other hand, the nitrate films showed a regular drop in *p*H from an average value of about 5.3 for new film to 2.3 after aging for 30 days. Correspondingly, high acidity was found also in every test of old nitrate film that was visibly deteriorated as a result of natural aging.

(*2*) *Stability Test of Nitrate Film.*—The stability test[4] at 134.5°C, used for testing pyrocellulose and guncotton, was found to be applicable to cellulose nitrate film. In this test, a 1-gram specimen is placed in a closed tube, with normal methyl violet paper inserted into the tube to about 2.5 cm. above the test specimen. The time required at a constant temperature of 134.5°C for the gases given off from the specimen to change completely the color of the paper to salmon pink is observed. The effects of oven-aging upon the stability of nitrate film as determined by this test are shown in Fig. 4. The curves for the different commercial brands are alike in general characteristics, showing slow rates of change of stability for the first two days of heating, then sharp breaks in the curves followed by much more rapid loss of stability. Old film, visibly deteriorated by natural aging, usually had a reaction time corresponding to 10 to 15 days of oven aging.

(*3*) *Copper Number.*—Some forms of degraded cellulose reduce copper from an alkaline solution of copper sulfate, and the amount reduced is considered a measure of the amount of such material present. In applying this test to films, the standard method[5] for testing the copper number of paper was used, except that the samples were prepared in the following manner: The film was dissolved in acetone,

and the cellulose ester precipitated in hot water, washed, and dried. The resulting samples were in soft fluffy form, comparable to the paper samples prepared by grinding. Both acetate and nitrate films were

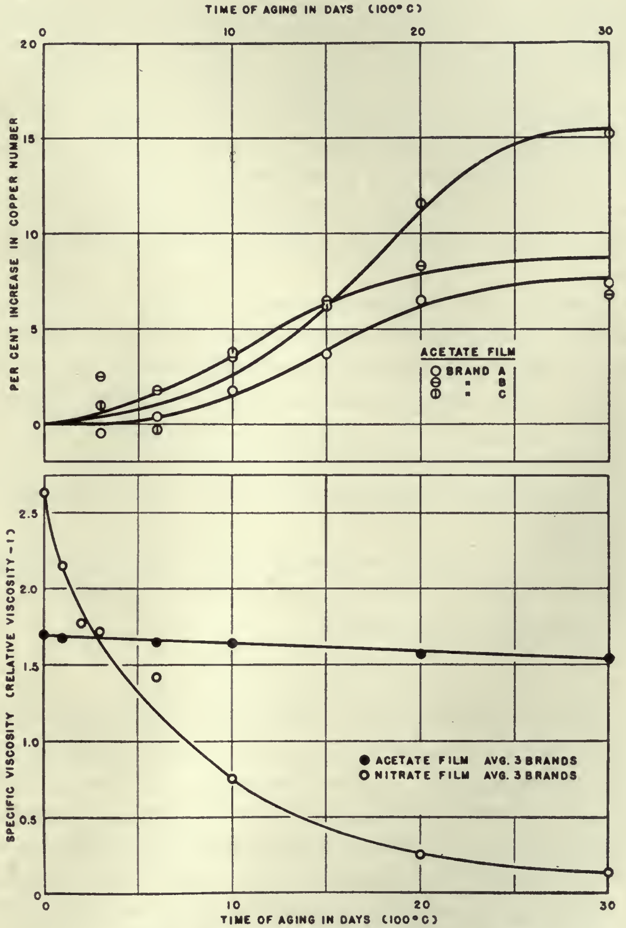

FIG. 5. (*Upper*) Effect of oven-aging upon the copper number of cellulose acetate motion picture film.

FIG. 6. (*Lower*) Effect of oven-aging upon the viscosity of cellulose acetate and cellulose nitrate motion picture films.

tried, but no figures were obtained for nitrate film because it dissolved completely in the alkaline copper sulfate solution.

The data on the copper numbers of three brands of acetate film

are shown in Fig. 5. Four series were run on each brand. The reproducibility of results was not very good, but in each instance there was an increase in copper number with aging. For 30 days of aging, the increases in copper numbers were 7,15, and 7 per cent, respectively, an average of about 10 per cent. Compared with the change occurring in stable papers, this would be considered a small increase, indicative of relatively high chemical stability. The initial copper number values for the three brands of film averaged 3.2, which is considerably higher than for permanent paper. This is not surprising when the more drastic chemical treatment used in making the acetate film is considered. Hence, the two materials are not comparable on the basis of actual values, but rather on the rate of change upon heating.

(*4*) *Viscosity.*—The relative viscosity of acetone solutions of the film base was found to be the most sensitive and reliable chemical test for following the deteriorative effects of aging upon both acetate and nitrate films. The viscosity data are of special interest because of the excellent correlation between changes of viscosity and loss of folding endurance upon aging. This good correlation between changes in physical and chemical properties indicates a sound basis for judging relative stability.

The molecular weight of substances with long-chain molecules is related to the viscosity of their dilute solutions, according to Staudinger,[6] by the following equation:

$$\eta_r - 1 = \eta_{sp} = K_m.c.M$$

where η_r is the relative viscosity, which is the ratio of the viscosity of the solution to the viscosity of the solvent; η_{sp} is the specific viscosity as defined by Staudinger; K_m is a constant; c is the concentration in primary mols per liter of solution; and M is the molecular weight. From this equation it can be seen that for equally concentrated solutions of the same K_m, the viscosity depends only upon the molecular weight. Consequently, any breakdown in the molecular structure should result in a lowering of the viscosity.

The effect of accelerated aging upon viscosity was determined by viscosity measurements before aging and after various aging periods. Specimens weighing 1.000 gram each were used. The test was made by dissolving the film base away from the emulsion in acetone, making the solution up to 100 milliliters in a volumetric flask, and measuring the time of flow of the solution in an Ostwald viscosity pipette

immersed in a constant-temperature water bath at 30 ± 0.02°C. The product of the time of flow and density of the solution, divided by the corresponding product for the solvent, gives the relative viscosity.

The results of ordinary oven-aging in dry air are shown in Fig. 6. This shows specific viscosity plotted against time of aging. The curve for acetate film shows very slow change. The decrease in specific viscosity for 30 days of aging was only from 1.70 to 1.54, or 9.4 per cent. For the same time of aging, the nitrate film decreased from an average value of 2.63 to 0.14, which indicates a complete

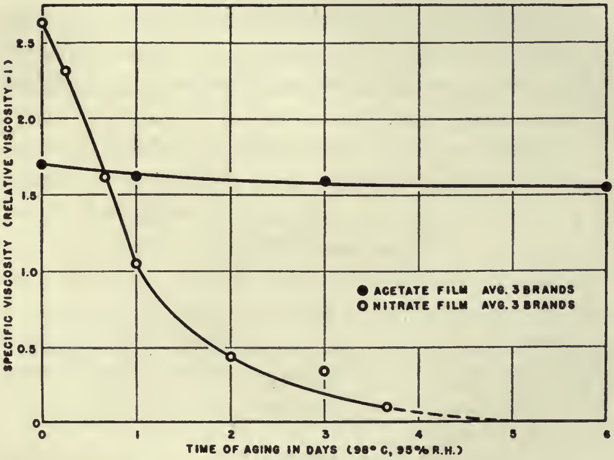

FIG. 7. Effect of oven-aging with high relative humidity upon viscosity of cellulose acetate and cellulose nitrate motion picture films.

change in structure. Old nitrate film badly deteriorated from natural aging gave a viscosity corresponding to about 10 days of oven-aging.

In order to determine the effect of high humidity, samples of film were aged suspended over a saturated solution of potassium sulfate in a closed bottle. The temperature maintained in the bottle was 98 ± 2°C, and at this temperature the relative humidity is 95 per cent. The results are shown graphically in Fig. 7. Under these conditions, decomposition was more rapid for both types of film, but especially for the nitrate film. The high relative humidity resulted in hydrolysis with the formation of nitric acid which greatly accelerated the reaction. The average time required for a decrease in viscosity

of 95 per cent was about 3 days, compared with 30 days for oven-aging in dry air. The decrease in viscosity of acetate film for 3 days of aging was 6.5 per cent. This is a greater change than for the same time of aging in a dry atmosphere (Fig. 6), but is small compared with the change found for nitrate film, and indicates excellent stability even under these extreme conditions.

(5) *Effects of Aging upon Gelatin Emulsion.*—Ordinary oven-aging in dry air had no effect upon the gelatin emulsion of acetate films so far as could be observed. The aging at 100°C, 95 per cent relative humidity, resulted in some softening of the emulsion and a tendency of the emulsion to separate from the base. The first visible evidence of deterioration of nitrate film with natural aging is a discoloration and softening of the emulsion. Tests of the emulsions from such films showed that oxidation, as indicated by relatively high ammonia nitrogen content, and hydrolysis as indicated by relatively high amino nitrogen content, had both taken place. Results of tests on the emulsion of oven-aged film showed that the oxidation was increased from 0 to 0.89 per cent and hydrolysis from 1.89 to 3.90 per cent by oven-aging. This apparently results from contact with the products of decomposition of cellulose nitrate, as there was correlation between the acidity of the film and condition of the emulsion. Hence, the softening of the emulsion of nitrate films often observed after natural aging may be said to be an indirect result of the decomposition of the cellulose nitrate film base.

VI. SUMMARY

On the basis of the test data, the cellulose acetate type of safety film appears to be a very stable substance. It is a comparatively new material on which no natural-aging data are available. However, data on the relative resistance to accelerated aging of the acetate film, nitrate film, and permanent-record papers are very favorable for the acetate film. A specification, proposed by Scribner,[7] for permanent-record paper of the highest quality requires a retention of folding endurance of 85 per cent after heating for 72 hours at 100°C. Acetate film retained 50 per cent after 150 days at the same temperature. Nitrate film, known to be relatively impermanent, had no folding endurance after 10 days of heating.

The relatively high chemical stability of acetate film is shown by the fact that aged samples showed no increase in acidity, whereas nitrate film became distinctly acid. For permanent-record paper, the copper

number must not be greater than 1.0 or increase more than 0.5 when heated 72 hours. The average value of the copper number of cellulose acetate was 3.2. This is higher than for permanent-record paper as would be expected as a result of the chemical treatment undergone in acetylation of the cellulose; but upon heating for 72 hours at 100°C, cellulose acetate showed an average increase of less than 0.5.

The best evidence of the high stability of acetate film is furnished by results of viscosity measurements. When heated for 72 hours at 100° C, the specific viscosity decreased about 2 per cent, and after 30 days of aging only 9 per cent. With nitrate film, the decrease was 35 per cent in 72 hours and 95 per cent in 30 days of aging.

While it is not possible to predict the life of acetate film from these results, the data show that the chemical stability of the film, with respect to oven-aging, is greater than that of papers of maximum purity for permanent records. On the basis of this comparison, cellulose acetate motion picture film appears to be very promising for permanent records.

VII. ACKNOWLEDGMENTS

Acknowledgments are made to J. E. Gibson and Meyer Reiss, Research Associates, for assistance in the investigation while assigned to this Bureau by the Division of Motion Pictures and Sound Recordings, National Archives.

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DISCUSSION

MR. TASKER: Can anyone tell us whether there is hope that within the next few years acetate base may be available for regular motion picture work as economically as the present nitrate base film or nearly so? At the present time there is quite a cost differential, nearly 100 per cent.

DR. CARVER: You will find a large number of positive opinions, probably, but you can take your choice. I think that is about as good an answer as you can get. "Is there a chance?" Surely, there is a chance. When you ask "Is there hope?" and want to know what the odds are, that is another thing.

MR. HOVER: About ten years ago a number of industrial firms employed 35-mm. acetate films, and the general opinion was that it would not stand the wear in the field.

Was that the fault of the equipment, or has acetate film been materially improved in that respect?

DR. HILL: Dr. Carver assured me that it is now a different product entirely. Otherwise, I have no definite information on it.

DR. CARVER: I did not mean to go quite so far: There is a difference in purpose involved. Dr. Hill's is concerned with permanence when the film is stored. What Mr. Hover is referring to has to do with the number of times the film can withstand going through a projector. They are two quite different things and bear no real relation to each other.

It is as true now as it was then, that acetate is not as strong as nitrate. It was true then as it is now that acetate will last very much longer than nitrate; that is, it is not as subject to deterioration.

CARE OF SLIDE-FILMS AND MOTION PICTURE FILMS IN LIBRARIES*

C. G. WEBER** AND J. R. HILL†

Summary.—*The stability of cellulose acetate film used as slide-films is being studied to determine its suitability for preserving records in libraries. Cellulose nitrate motion picture films are being tested to find the best conditions for preserving this type of film. The control of moisture content is essential to prevent brittleness in acetate films, and scratching of the emulsion appears to be a problem involved in the use of slide-films in reading projectors. Frequent cleaning is important. Nitrate motion picture films are not permanent because the cellulose nitrate is unstable. They can be best preserved by storing in a dry atmosphere, at low temperature, in such manner that products of decomposition are permitted to escape freely. The storage of nitrate films requires very exacting fire prevention measures.*

I. Effects of atmospheric variations upon films
   (*1*) *Moisture content*
   (*2*) *Flexibility*
   (*3*) *Expansion and contraction*
II. Scratching of slide-films
III. Cleaning films and slide-films
IV. Problems in storing cellulose nitrate film
V. Summary

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* Received October 12, 1936; presented at the Fall, 1936, Meeting at Rochester, N. Y.

** National Bureau of Standards, Washington, D. C.

† Research Associate at the National Bureau of Standards, representing the National Research Council.

This study was made with the assistance of a fund granted by the Carnegie Corporation to the National Research Council, and a fund allotted by the National Archives, and with the advice of the following Committee, appointed by the National Research Council: R. C. Binkley, National Association of Learned Societies; J. G. Bradley, National Archives; E. K. Carver, Eastman Kodak Co.; H. T. Cowling, National Archives, representing the SMPE; V. B. Sease, Dupont Film Corp.; F. W. Willard, National Research Council, and H. M. Lydenberg, *Chairman*, New York Public Library. The Committee on the Preservation of Film, of the SMPE, also coöperated in the work.

Progress made in the use of photographic film for copying, in miniature, important reference records, and the apparent certainty of widespread expansion in the use of films for many classes of library records, make the care and preservation of films a problem of immediate importance to librarians. The term slide-film is applied to films used for projecting enlarged still pictures upon a screen for comfortable reading. They can be either in roll or card form. Two kinds of film are available for this purpose: (*1*) cellulose nitrate, which is very inflammable and chemically unstable, and (*2*) cellulose acetate ("safety film"), which is slow-burning and chemically stable. Both kinds have been used for copying documents in miniature, but at present only safety film is in general use for this purpose. Acetate film presents no greater fire hazard than ordinary paper, and although the safety film now used is a comparatively new material, it has been found at the National Bureau of Standards* to be very stable, if properly made and processed. However, the preservation of acetate film requires control of moisture content.

Cellulose nitrate is in general use in the motion picture industry chiefly because cellulose acetate is more brittle when dry, curls more in service, and is slightly plastic when wet; consequently, it is not entirely satisfactory for continuous machine development. The samples tested were furnished by the three principal domestic manufacturers of motion picture films, and were said to be representative of current commercial products. No materials of foreign manufacture were tested.

The National Archives and other depositories interested in the storage of valuable motion picture films have special problems due to the highly inflammable character of the base. The base of this type of film is a mixture of cellulose nitrate and camphor. It is chemically unstable and highly combustible.

I. EFFECTS OF ATMOSPHERIC VARIATIONS UPON FILMS

The effects of variations in relative humidity of the surrounding air were determined by studying the properties of film over a wide range of relative humidity at constant temperature. The properties tested were: moisture content and its effect upon flexibility as de-

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* Detailed information on the stability of films will be contained in a separate article now in preparation.

termined by the Pfund* type of folding-endurance tester, and dimensional changes. Inasmuch as the experience of film users has indicated that acetate film is much more susceptible to atmospheric changes than nitrate film the relative behavior of these two types is significant. The films were conditioned for 24 hours in all instances, because both types of film were found to reach practically constant weight within that time.

(*1*) *Moisture Content.*—The moisture contents of cellulose acetate and cellulose nitrate film, in common with other hygroscopic substances, tend to follow the relative humidity of the surrounding atmosphere. With films, changes of moisture content affect the flexibility and cause dimensional changes. Hence, the relationship between relative humidity and moisture content is of interest in that it gives the basis for explanation of the physical reactions of the films to moisture changes. This relationship is shown graphically in Fig. 1. The data on moisture content of films are based upon oven-dry weights. Oven-dry weight was obtained by heating for 1 hour at 100°C, with a slight correction for a permanent loss of weight due to loss of volatile material. The graph shows absorption and loss of moisture for both acetate and nitrate films with emulsion. These curves are similar in general form to adsorption-desorption curves for paper.[1] It will be noted that there are two curves for each type of film, which is because the moisture content of a hygroscopic substance varies according to the direction of approach to the hygrometric condition. Hence, we have one curve for absorption, that is, ascending from a dry initial condition, and one curve for descending values. This variation in moisture content, as influenced by the history of conditioning, is known as hysteresis.

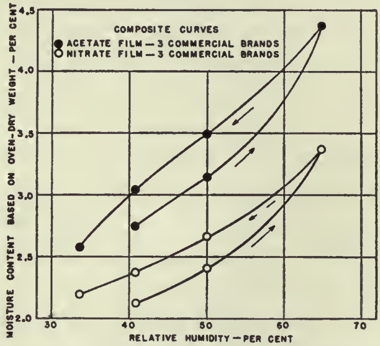

FIG. 1. Relation between relative humidity and moisture content of cellulose acetate and cellulose nitrate motion picture film.

* This type of folding tester developed by A. H. Pfund, of Johns Hopkins University, for the Dupont Film Mfg. Corp., was used in the study at the Bureau after it was found to give more reproducible results than did folding testers used for paper.

(*2*) *Flexibility.*—The relationship between folding endurance and relative humidity was found to be fairly regular for both acetate and nitrate film. The loss of folding strength with decreasing relative humidity was more rapid for acetate than for nitrate, which apparently explains why brittleness difficulties are more frequently encountered in the use of safety film. The relationship between the hydrometric condition and flexibility of both acetate film and nitrate film is shown in Fig. 2. Data were obtained for the relative humidity range from 30 to 85 per cent, as shown by the curves. Extension of the curves below 30 per cent relative humidity by extrapolation is shown by the broken lines. The only data for this region were obtained on film dried over calcium chloride in a desiccator. Neither

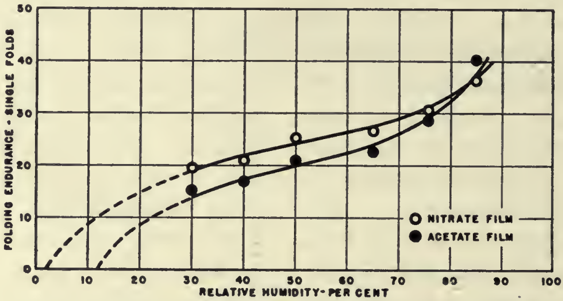

FIG. 2. Effects of relative humidity upon flexibility of cellulose acetate and cellulose nitrate motion picture film.

type would withstand folding under these conditions, indicating complete loss of folding endurance before zero relative humidity was reached. The extrapolation would indicate extreme brittleness of the acetate film at a relative humidity of about 15 per cent and below. This agrees with the experience of users. Hence, since 15 per cent is within the range of humidity encountered during the winter season, in heated rooms with no humidity control, some air-conditioning precautions appear essential for the storage of safety film. From a consideration of the folding-strength data and some other factors involved, a relative humidity of approximately 50 per cent would appear to be satisfactory. This value is high enough to prevent brittleness, and it does not introduce the condensation problems that might be encountered at higher humidities. Also, 50 per cent humidity is well within the comfort zone, and is economical for year-round control. Fortunately, this humidity is the same as that found satisfac-

tory for the preservation of books in libraries;[2] therefore, the use of slide-films presents no storage problems for libraries provided with conditioned air.

In libraries without conditioned air, satisfactory conditioning of films can be accomplished by means of humidification in small, closed rooms or cabinets. Small, closed rooms can be humidified with simple, relatively inexpensive air-conditioning units. This method has been employed successfully at the Library of Congress for slide-film storage space. Cabinets or small vaults can be humidified by using open vessels of the proper salt solution. A saturated solution of sodium dichromate, $Na_2Cr_2O,2H_2O$, because it gives a relative humidity of 52 per cent at 68°F, should prove very satisfactory for the purpose. The solution should be exposed in shallow vessels with fans blowing air across the surface to promote the circulation of air. Inasmuch as considerable water may be absorbed from the air, an excess of dichromate should always be used to insure saturation.

Acetate slide-films should be stored in the conditioned chamber when not in actual use. In order to assure sufficient contact with the humidified air to permit films to regain the moisture lost during projection, they should be stored as open reels without cans. When placed in the humidity room, all tightly wound rolls should be loosened and hung exposed, so that the air will have free access to all parts of the film. Successive projections drive out the film moisture more rapidly than it can be regained while tightly wound, and film in frequently used rolls may become brittle even when stored in the humidified atmosphere between projections, unless proper precautions are taken. Acetate film that has become brittle, through excessive drying, will regain its flexibility without permanent damage if the moisture is restored. Moisture penetrates a tightly wound roll of film very slowly, and it will require weeks to recondition a roll of brittle film properly, if the roll is not loosened to permit the air to get between the convolutions of film. Thorough conditioning can be accomplished in 10 to 30 minutes by passing the film through a humid chamber or by other methods such as moistening with a mixture of water and a water-miscible volatile liquid as suggested by Crabtree and Carlton.[3] However, such methods are inconvenient for the average library, and are not considered necessary for conditioning the small rolls of film used as slide-films. Nitrate film has better folding endurance at low humidity than acetate film, and is less prone to break in use when dry. Hence, humidity control is less essential

for nitrate film from the standpoint of flexibility. Slide-films in card or strip form that are not subject to winding upon reels do not require moisture-content control if carefully handled when dry.

(3) *Expansion and Contraction.*—All changes of moisture content of films are accompanied by expansion or contraction. The dimensional changes resulting are not important to users of slide-films except as uneven dimensional changes may cause curling of the films, and that is rarely sufficiently pronounced to give serious difficulty in a well designed projector, as standard sprockets are made to allow for

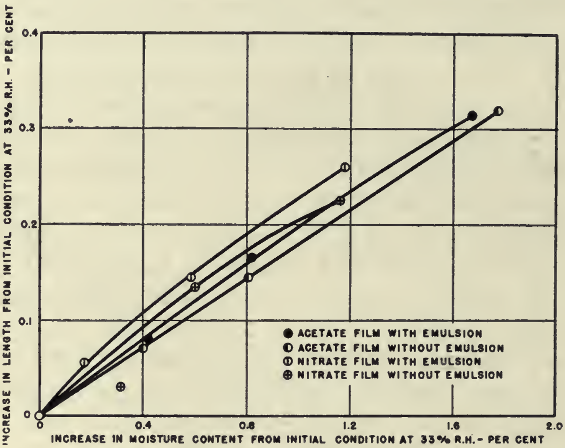

FIG. 3. Relation between moisture content and dimensions of cellulose acetate and cellulose nitrate motion picture film.

a shrinkage of 1.5 per cent. The relationship between increase of moisture content and expansion of films is shown in Fig. 3. It will be noted that there is little difference between the two types of film as regards changes of dimensions per unit of moisture change. However, the changes of moisture content accompanying atmospheric variations are greater for acetate film, as shown in Fig. 1. Furthermore, the acetate film always tends to curl more than the nitrate. However, the expansion and contraction of film is considered a serious problem in film processing, but does not often give trouble in the projection of films.

Film shrinkage not caused by loss of moisture is caused by loss of volatile material. With acetate film this is confined to the loss of

some traces of solvents, and possibly some plasticizer, during the first 6 months, after which there is no further measurable permanent change. Nitrate film shrinks more or less continuously throughout its life because of the loss of solvents and of volatile decomposition products. Thus, printing from old nitrate negative will often require pulling the film down frame by frame in step printers, because the shrinkage will cause too much creep for continuous printing.

II. SCRATCHING OF SLIDE-FILMS

Examination of slide-films that have been used in reading projectors over a period of time has revealed considerable scratching, particularly on the emulsion side. Fig. 4 shows a section of film that had been in use in a public library for a period of less than 2 years. This photograph was taken by reflected light to show the actual extent of damage. The scratching has not in this instance reached the stage where legibility is seriously impaired. However, it apparently brings up a problem in connection with the care and use of slide-films. If the scratching can not be avoided through improvements in the design of projectors and by keeping the films clean, it appears that the negative films of important records should be carefully preserved. It may be necessary to replace from time to time positives that receive an excessive amount of use in projectors, because of the accumulation of scratches. None of the commercial scratch-proofing treatments was tested for the purpose of determining effectiveness in preventingscratching.

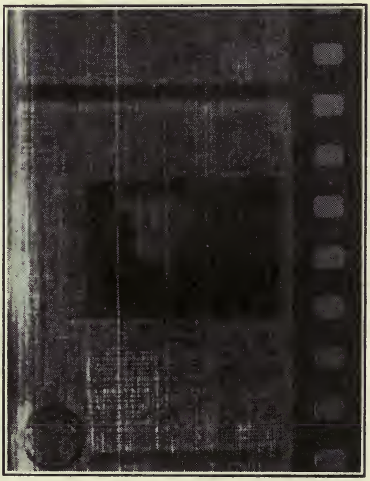

FIG. 4. Scratches on cellulose acetate film, resulting from normal use in projector.

III. CLEANING FILMS AND SLIDE-FILMS

It is important that film be kept clean, not only because extraneous material on the film affects legibility, but because dust particles cause scratching of the film when in use. The Bureau has found chemically

pure carbon tetrachloride to be quite satisfactory as a cleaning fluid. It is a good solvent for fats and oils, evaporates readily, is noncombustible, and does not have any measurable effect upon the stability of the film. However, the fumes from this liquid are rather toxic and should not be inhaled. The use of this and other cleaning liquids is described by Crabtree and Carlton.[3] They recommend that the film be wiped gently with a silk plush moistened with the cleaning liquid. It is stated that cleaning machines suitable for roll films are available commercially, and that their use is preferable to cleaning by hand. Film subject to intermittent use should be inspected at regular intervals for dust, finger marks, or traces of oil from the projectors that may make cleaning necessary to preserve the legibility and prevent scratching.

IV. PROBLEMS IN STORING CELLULOSE NITRATE FILMS

Nitrate motion picture film presents special problems of storage and handling because of its highly combustible nature. It has a low ignition temperature combined with a high rate of combustion, and is capable of decomposition with little or no air supply, evolving poisonous inflammable gases. Standards for handling and storage have been established in the regulations of the National Board of Fire Underwriters.[4] However, storage from the standpoint of the preservation of valuable film requires not only the protection of the surroundings in the event of a fire within a storage vault, but the proper isolation of films within the vault so that only a minimum quantity of film will be destroyed in case of fire. Crabtree and Ives[5] found it possible to construct cabinets with metal-lined, insulated, individual film compartments that would prevent the complete burning of single rolls of film from igniting other film in the cabinet. Such cabinets are now available commercially, and their use inside safety vaults of suitable fireproof construction[4,6] should afford adequate protection from fire. This system has been followed in the construction of the film-storage facilities at the National Archives.[7]

Film of the nitrate type is perishable because the cellulose nitrate base is unstable chemically. Deterioration is accelerated by increasing temperature or moisture, raising the pressure, or by contact with the products of decomposition. Hence, storage compartments and containers should be so vented as to prevent any accumulation of gases to raise the pressure as might result in sealed containers, or to injure the film by contact. Also from the standpoint of preserva-

tion, the lower the temperature and humidity the better. However, the advantages to be gained by storing at temperatures below about 50°F are probably more than offset by the added costs of air-conditioning, and the tempering difficulties involved to prevent condensation when film is taken out of storage. Relative humidity above 50 per cent is not recommended in any case. Even when stored under the most ideal conditions, nitrate film can not be expected to last indefinitely, and valuable film should be inspected regularly for signs of deterioration. Protective duplications should be made as soon as deterioration is evident, and it appears to be desirable to reproduce the negatives of permanent-record value on the more stable acetate base before deterioration is evident.

V. SUMMARY

The cellulose acetate film used as slide-films for records is hygroscopic. It adjusts its moisture content to conform to the humidity of the surrounding air, and changes in moisture content affect its properties.

The film is brittle under the conditions often encountered in rooms without air-conditioning, making control of the moisture content essential. The conditions suggested for storage and use of film are those recommended for the preservation of books in libraries, namely, relative humidity of 50 per cent and temperature of 70° to 80°F. However, libraries without conditioned air can get satisfactory performance by storing the slide-films in humidified cabinets or small rooms in which the relative humidity is not permitted to drop below 50 per cent. Control of temperature is not considered essential, except that extreme variations should be avoided.

The emulsion side of film is easily scratched, and despite care in handling, projecting, and cleaning to minimize abrasion, slide-films accumulate scratches. The positives in constant use may require occasional replacement; hence negative films of important records should be carefully preserved as a source of replacement.

Nitrate film is perishable and highly combustible. Storage of this type of film should be undertaken only in approved fireproof cabinets, and these should be within vaults of fireproof construction. Low temperature and low relative humidity are recommended to retard the deterioration of film in storage. Film containers for nitrate film should be vented to permit free escape of the products of decomposition (principally oxides of nitrogen) since their presence accelerates

deterioration. It appears advisable to preserve pictures of permanent value by making negatives on acetate base, because of the perishable nature of nitrate film.

The authors are indebted to J. E. Gibson and M. Reiss for assistance in the work while assigned to the Bureau bv the National Archives.

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DISCUSSION

MR. RICHARDSON: Is it implied that it makes no difference whether film in a theater be stored in an atmosphere that is humid or not?

MR. WEBER: No. In none of this work have we been interested in mechanical wearing properties except in respect to the acetate film. At low relative humidity we know the film is brittle, and we have tried to find the reasons why, so as to point out what precautions were necessary. We have not tried to determine what precautions are necessary to maintain good wearing qualities in nitrate film. Certainly film that is projected a number of times and dried, not only by the heat of the projector but by storage in hot surroundings, will become dry to the point of becoming brittle. We did not feel that that was part of our problem. Everyone recognizes the fact that it is so.

MR. RICHARDSON: In a great many theaters film is being stored without any humidity control whatsoever. Would a higher humidity be beneficial or not?

MR. WEBER: It would be beneficial from the point of view of life and durability. Tightly wound films would not benefit very much.

MR. RICHARDSON: Has the Eastman Kodak Company ever established any conditions relative to drying film before release by the producers?

MR. CARVER: I believe not, although Mr. Crabtree has made some recommendations in a few of his writings.

MR. TASKER: That really is the problem of the release print laboratories and of the exchanges that handle the releases.

MR. FINN: The question of drying has been taken up by the Projection Practice Committee, which on several occasions recommended that film in the theater should be stored in vaults in which the humidity of the atmosphere is comparable to that of the outside air. That would assure some degree of humidity, and would allow the gases to go off.

Rear shutters on the projectors would solve a lot of such problems. The theaters are not using them, and much trouble results from their absence. A rear shutter will reduce the heat by 50 per cent, at least, and having cut the heat to that extent, the film will not become dry and brittle.

I believe that much of the trouble we are encountering with release prints is due to a lack of sufficient numbers of prints for the runs on given pictures, with the result that each print is literally run to death. There are not enough films to go around, and that is responsible for most of the trouble.

MR. TOWNSEND: Buckling is not caused by heat applied to the center of the film or to the picture part of the film through projection, but by the fact that the edges of the wound reel become dry faster than the protected center, and consequently the edges shrink more than the center, causing the center to buckle back and forth. If film that has dried in such a condition is kept running in the projector, exposed to the heat of the arc light, it will eventually become dry throughout, and become flat again.

MR. CRABTREE: Buckling of new film is often due to the fact that during processing the film is dried at too high a temperature. This results in a "skin effect," wherein the surface of the gelatin is dry, while the lower layers are not as dry, so that if the film is wound up immediately and then projected, distortion of the gelatin occurs. We recommend drying the film in the laboratory at a temperature of about 80° to 85°F at a relative humidity of about 70 per cent.

MR. KURLANDER: I wonder whether the edge drying is not partly due to the conduction of heat from the metal parts of the projector that are heated by the spot on the aperture plate. Only the edges of the film are in contact with the metal parts of the projector, the sprockets, and the shoes of the aperture.

MR. GRIFFIN: A report was made recently by Professor Hardy in which it was shown that the temperature of the aperture plate, which, of all points in the projector, might be expected to reach the highest temperature, was less than 212°F with the rear shutter operating. It is evident, therefore, that there is not a very great deal of heat in the parts mentioned by Mr. Kurlander in a modern projector having a rear shutter.

Mr. Finn's statements, of course, were more nearly correct in regard to projectors without rear shutters, because it is true that in many instances the film trap assemblies reach such temperatures as to draw the temper from the film track shoes on the film trap. The solution, of course, is the universal use of rear shutters.

MR. KURLANDER: Has anybody else observed whether a film buckles when a rear shutter is used?

MR. TOWNSEND: Film buckled before we had rear shutters, and still buckles.

I advocated rear shutters long ago, before sound came into the pictures, and asked the manufacturers to design them. But no rear shutter will put elasticity back into a film that has had its edges dried by being stored in a dry atmosphere.

MR. WOLF: Perhaps Mr. Griffin could tell us what is the difference of temperature of the aperture with and without the shutter.

MR. GRIFFIN: In modern rear shutter design the temperature in some instances may be reduced by approximately two-thirds.

MR. WOLF: I was asked this summer at the International Standards Conference whether film was being made containing certain percentages of nitrate and acetate combined. I had thought that film was exclusively nitrate or exclusively acetate. Is such film being made?

MR. CARVER: Yes. Some film is made of nitro-acetate and some of mixed nitrate and acetate. I believe in France and in Germany some film is being made of nitro-acetate.

MR. WOLF: No motion picture film in this country is made of nitrate and acetate combined?

MR. CARVER: X-ray film has a small percentage of nitrate in some of the under layers.

MR. WOLF: The standard 16-mm. film in Germany has, I understand, some nitrate in it. I do not know what the percentage is.

MR. CRABTREE: Mr. Weber, suppose we condition a piece of film at a relative humidity of, say, 10 per cent, and wind it into a tight roll; how long will it take at a humidity of 70 per cent for the entire roll to reach equilibrium?

MR. WEBER: We have checked up on 35-mm. film that has been in the humidity room for more than a month, and it was definitely not in equilibrium. With the 16-mm. acetate film I do not imagine there would be much difficulty. As to the 35-mm. film in tight rolls, I doubt whether it would become conditioned in six months.

We have that same problem in connection with paper. Paper in a large, tight roll will not become conditioned within a year farther than about an inch from the ends of the roll. Besides, the paper has a much lower finish than the film so that the air would have better access than in the case of film. My guess is that it would be very doubtful whether a 35-mm. film would become conditioned in a six month's period in tight rolls.

MR. CRABTREE: Speaking of film containers, we must consider what may happen in very damp tropical climates. It is very difficult to maintain low relative humidities, and I do not think it would be safe to recommend cardboard containers. I think that metal containers should be insisted upon.

MR. WEBER: I would not recommend cardboard containers for acetate film unless there were a vault under some sort of control. Unless there is some way of drying the air it certainly would be extremely dangerous to store the films under such conditions.

VISUAL EDUCATION AND SLIDE-FILMS*

J. B. MacHARG**

Summary.—*The invention of flexible film and Mazda light made possible slide-films having great advantages as to convenience and cost. The necessity of a fixed series of slides introduces problems that have not yet been recognized in the production of much of the material now available, and definite principles should govern the production of slide-film sequences.*

The many advantages are as yet little known. Their convenience and negligible cost make their wider use desirable. At least three machines, adapted for this kind of slide, will soon be available.

Most film stereopticon positives now used in educational work are single-frame. The double-frame positive has some inherent elements of superiority, and there is a great advantage in that equipment is available for its production by any advanced amateur. Slide-films are the least expensive and most convenient of all devices for visual teaching by light projection, and open a broad field for important development.

During the past twenty years, many efficient machines for both hand and automatic projection of single-frame pictures on 35-mm. film have been placed upon the market and are widely used both in schools and in business. The 35-mm. film moves vertically in these projectors. All educational slide-films to date have been made by a comparatively small number of producers, using specially built apparatus. Although open to criticism, the richness of illustrative material offered is not recognized by teachers in general, and prejudices have grown up against miniature slides. For the lack of better material in slide-films, we, educators, are at fault; not one teacher in a thousand has given a thought to the problem of supplying the urgent demand.

From a technical standpoint, much of the slide-film material is poor. Most of it has been made by copying paper prints. If single-frame slides are made by projection directly from 5×7- or 8×10-inch negatives, screen images can be produced that can not be distinguished by the untrained observer from standard $3^1/_4 \times 4$-inch

* Presented at the Spring, 1936, Meeting at Chicago, Ill.

** Professor of American History, Lawrence College, Appleton, Wis.

slides. Films of such quality are easily made, but it involves the comparatively expensive and arduous task of making large original negatives, and reduction by projection in printing the miniature positive, which, again, demands costly apparatus. No precision, single-frame camera, for general work, with accessories for copying, has been available. Such a machine might have avoided seeming defects in single-frame technic, which, it is believed, are not inherent.

The crying need for such a camera has been supplied, in part, by the introduction of German instruments of great excellence, with innumerable accessories for the convenience of the slide-film photographer, employing, however, a double frame, with the film running horizontally in both camera and projector, provision being made also for vertical pictures.

Today there are more than 25,000 enthusiastic workers producing double-frame slide material in great quantities, from which are emerging some excellent slide-film sequences, giving results upon the screen equal to those achieved by the use of the standard $3^1/_4 \times 4$-inch slides.

The problem of making a stereopticon that will project both single- and double-frame slide-films, either vertically or horizontally, and individual miniature slides, as well, has been met by at least two of our best producers, and their machines will be upon the market in the near future.

The situation that has arisen raises the question of the relative merits of single- and double-frame slides. Of course, a slide double the size of another has inherent advantages; but insomuch as in most educational work the average number of students in a class is, or should be, not much greater than twenty-five, a screen image of 30×45 inches is ample, and a satisfactory picture can be obtained from a single frame. Because of the advantages of lower cost, greater compactness and convenience, the desirable tendency, at least for some types of illustration, would seem to be toward smaller frames on 16-mm., or even 8-mm., stock, rather than toward apertures larger than the standard single frame.

There is, of course, no question that $3^1/_4 \times 4$-inch glass slides and large slide-films produce better pictures than smaller ones; but the advantage is one of small practical importance in such work. Differences appear under high magnification or at close range, but the resolving power of the eye is limited, and if the differences can not be detected at normal viewing distances, with screen images

of satisfactory size for teaching, the small slide is just as good as the larger. The theoretical and actual powers of the eye and the sharpness of screen images have been well discussed by Zieler,[1] to whose manual the reader is referred for further treatment of this subject.

The double frame has two marked advantages, which should not be overlooked. Color is of great importance in educational work, and the double frame makes detailed tinting practicable and comparatively easy. Second, many insets, dictionary illustrations, *etc.*, are no larger than the double frame, and these can be copied by the apparatus of miniature photography quite as well as by any other method.

Aside from optical and other limitations, which must be admitted, slide-film sequences have a fixed order, which many teachers deem a great disadvantage. Most of the educational slide-films so far produced embody illustrations for the study of geographical, literary, or economic subjects, with accompanying notes, following an order that seems logical to the maker of the films, but not to all users.

Another definite type of slide-film follows a sequence of development fixed by the nature of the subject, and aims to teach a series of facts by the technic of the film. There are few of such films in existence. They offer abundant scope for pedagogy, and their number should increase.

The two great advantages of slide-films are economy and convenience. The two great disadvantages are, first, projectional deficiencies, by which is meant deterioration through scratching and buckling, and the difficulty of keeping glass pressure plates and films clean. Frictional electricity helps to gather particles of lint and dust, so that perfectly clean screen images are rare in all slide-film work. The second disadvantage is the fixity of order of the frames, which is somewhat mitigated by the fact that an experienced operator using one of the machines built for greatest convenience in teaching can choose and insert any frame of a slide-film almost as quickly and easily as he could a glass slide.

To supplement the slide-film and to obviate most of the disadvantages named, there is a growing use of individual miniature slides, for which some projectors now in use, and others soon to appear, provide. The small glass slide, produced by the same processes used in making $3^1/_4 \times 4$-inch slides, has the same advantages of cleanliness and durability, but at present costs more to make and seems rather less convenient for filing and handling.

For the individual film not mounted in glass, there would seem to be a possibility of extended use that is not yet appreciated. A single- or double-frame slide, cut from 35-mm. slide-film positive, may be easily mounted upon thin cardboard; or better, a folder of heavy paper, $3^1/_4 \times 2$ inches in size. Miniature positives may also be printed on $3^1/_4 \times 2$-inch film stock, obviating the necessity of mounting. Five hundred of such slides weigh about a pound, about one-sixtieth of the weight of a like number of standard slides, and are exceedingly compact and convenient to use. The slide, of either type, is placed for projection between jointed glass plates of the same size, or slipped in a glass slide carrier, made by hinging two glass plates, one $6^1/_2 \times 2$ inches, the other 7×2. This allows for a center stop of cardboard $^3/_4$ inch wide, which should be of the same thickness as the slide.

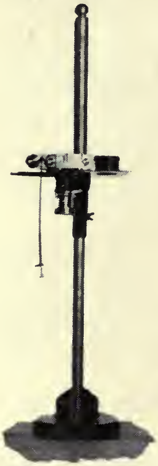

Fig. 1. Inexpensive camera stand.

Individual slide-films made and projected as described show no tendency to buckle from heat, and are only slightly subject to the inevitable dangers of scratching, which a slide-film can not escape. A Kodapak envelope, easily replaced when worn, affords protection to the film and interferes little with the projection. In practice its use seems unnecessary, because with care, the film and glass surfaces can be maintained intact, clean, and free from disturbing particles of dust. One important reason why strip and single slides have not been more widely used in teaching lies in the fact that until the advent of the 35-mm. precision camera, it was unduly expensive to obtain slides that the individual instructor might desire. Amateur production was impracticable, and but few photographic establishments were ready to make the slides.

The best of the 35-mm. miniature cameras on the market today, and the necessary copying attachments, involve a comparatively large initial expenditure; but once possessed, they open boundless opportunities for visual instruction with slides at trifling cost and a minimum of labor.

Anyone who can aim a camera and push a button can make astoundingly good slide-films of outdoor subjects. If the most expensive films are bought at retail and the luxury of professional processing is enjoyed, the resulting slides will cost four or five cents

apiece. If film is bought by the roll, and the work is done by oneself, the cost can be reduced to the neighborhood of one cent.

Copying pictures, maps, charts, and materials of all kinds for teaching is not so simple as landscape photography, but the difficulties are not great. A substantial stand to hold the camera is necessary. Fig. 1 shows one weighing 50 pounds, made by a local mechanic for $3.80. A great advantage of this method of copying is speed. If materials are fairly uniform, 40 copies an hour can be made with ease. Under favorable conditions, copying successive pages of books or manuscripts may be much more rapid. Accurate focus is assured by the use of a 30*x* magnifier. No attempt will be made to describe the numerous uses of the precision camera in the preparation of slides. Direct photographs of almost anything, and copies *ad libitum* of newspaper and magazine maps, charts, pictures, *etc.*, may be recorded by the camera and used upon the screen a few hours later.

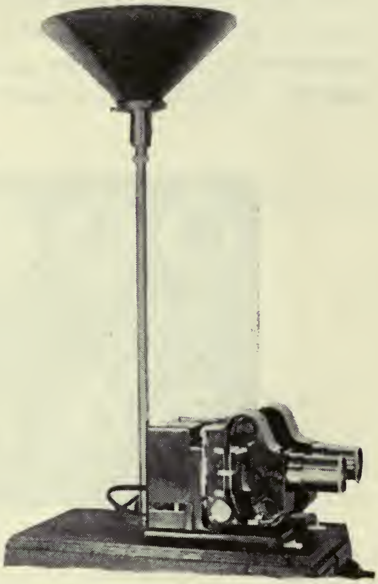

FIG. 2. Switch-box, with instantaneous switches, matched pair of projectors, and room light.

Slide-films are so inexpensive that each teacher may have his own supply always at hand. They require so little space—a 4 × 5-inch box holds 300—and it is so easy to get just what is desired, at the moment required, that they *are* used. Standard slides may be better but their cost and the trouble of drawing them from a central collection and later returning them militates against the free and incidental showing of slides as an every-day means of instruction, which is the life of visual teaching.

From the small negative, by the use of an enlarger, $3^1/_4 \times$ 4-inch slides can be made when necessary for use in standard machines, with which most institutions are equipped. Such slides are practically as satisfactory and are much less expensive than those made from larger negatives.

In all work in visual education there is great advantage in the use of two machines, so that there may be simultaneous showing of map and illustration, or comparison of two related objects. The difficulties attendant upon the use of a slide carrier are removed and the danger of overheating is lessened. There is the added advantage, and not an inconsiderable one, in the possible use of a rheostat for dissolving views, or an instantaneous switch, which is quite as useful.

Fig. 2 shows a convenient arrangement of apparatus for slide-film work, consisting of two matched projectors placed upon a switch-box, with a 300-watt lamp for use when it is not convenient to make connection with the room-lighting circuit. Two pairs of knife-switches, each pair with a single blade, provide for shifting current

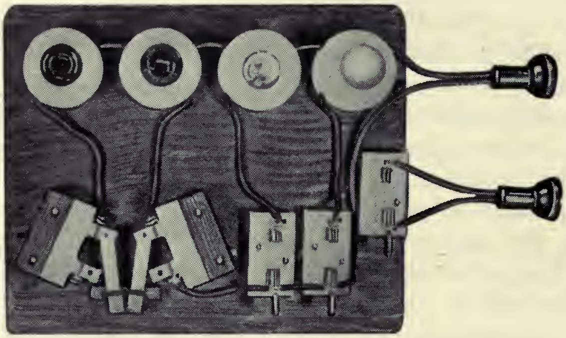

Fig. 3. Switchboard with instantaneous switch.

from one machine to the other in a fraction of a second (Fig. 3). The second pair is convenient when a single machine is used making possible a rapid change from slide to normal room illumination. While most stereopticons can be used with light sufficient for writing, it is a great help in teaching to have screen-image or full lighting instantly at command by the throw of a switch.

One great drawback to the popularity and extension of visual teaching is the additional work it demands. Equipment that makes the use of a stereopticon easy and agreeable is more important than is usually recognized. A simple switchboard with a makeshift instantaneous switch is easy to make and costs about one dollar.

The materials for the more complete switch-box, shown with the pair of projectors in Fig. 2, cost about three dollars. Inasmuch as

one highly efficient slide-film projector is now sold at $22.50, two of these machines equipped for individual slide work and with switchboard and room light might be produced to sell at not more than fifty dollars. Nothing would be more likely to advance the cause of visual instruction in schools. At present, teachers generally do not appreciate how much easier and how much more efficient their work would be with helps that are not difficult to supply. The practice of visual teaching is greatly stimulated by supplying the needs and desires of the individual teachers. The possibility of easy production by the amateur at small cost, of tolerably good and thoroughly serviceable slides of any subject, will open an ever-growing field for the use of slides in schools and colleges.

REFERENCE

[1] ZIELER, H. W.: Leica Manual, *Morgan & Lester* (New York, N. Y.), p. 49.

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SOCIETY ANNOUNCEMENTS

PACIFIC COAST SECTION

Election of Officers and Managers of the Section for 1937 are now in progress, the following members having been nominated for the offices indicated:

Chairman,	K. F. Morgan
Secretary,	C. W. Handley
	G. A. Chambers
Managers,	H. W. Moyse
	J. O. Aalberg
	L. L. Ryder

Of the two nominees for Secretary, one is to be elected; and of the three nominees for Manager, two are to be elected.

A West Coast Office of the Society has been established in Hollywood under the management of Mr. Walter R. Greene, who has been appointed to carry on the publicity and office work in connection with the activities of the Local Section. Mr. Greene's long association with the motion picture business and with *Variety* give him a background that will prove especially valuable to the activities of the Society and, in particular, to the West Coast Section. Mr. Greene's headquarters will be in the Equitable Building, Room 226, Hollywood Blvd. at Vine St., Hollywood, Calif.

ATLANTIC COAST SECTION

At a meeting held on November 17th in the auditorium of the Bell Telephone Laboratories, Inc., New York, Mr. A. C. Keller, of the Bell Telephone Laboratories, Inc., presented a paper entitled "Direct Recording and Reproducing Material for Disk Recording." The paper was followed by a very complete demonstration of recordings made on disks of various compositions, by both the lateral-cut and the vertical-cut methods. The demonstrations showed the effects of the materials upon frequency characteristics, surface noise, life, distortion, *etc.*

Election of the Officers of the Section for 1937 is now in progress, and the results will be announced in the next issue of the Journal.

MID-WEST SECTION

At a meeting held on November 12th in the auditorium of the Bell & Howell Engineering Laboratory at Chicago, two papers presented at the Rochester Convention were re-presented:

"Trick and Process Cinematography," by J. A. Norling, Loucks and Norling Studios, New York, N. Y. The paper was read by Mr. R. F. Mitchell, and a film demonstrating the various effects was projected.

"A Third-Dimensional Effect in Animated Cartoons," by J. E. Burks, Fleischer Studios, New York, N. Y. The paper was read by Mr. C. H. Stone, and was followed by a cartoon, *Musical Memories*, illustrating the effects described in the paper.

To conclude the meeting, a description of the highlights of the Rochester Convention was read.

The next meeting of the Section will be held on Thursday, December 10th, at which time the results of election of Officers of the Section for 1937 will be announced.

HOLLYWOOD CONVENTION

As announced in the previous issue of the JOURNAL, the next Convention of the Society will be held at Hollywood, Calif., May 24th to 27th, inclusive. These dates have been chosen in order that delegates may avail themselves of the summer tourists' railroad rates, which go into effect May 15th.

The following table lists the railroad fares and Pullman charges to Hollywood from various important centers:

City	Railroad Fare (round trip)	Pullman (one way)
Washington	$120.75	$20.50
Chicago	86.00	15.75
Boston	132.80	22.25
Detroit	98.30	18.00
New York	126.90	21.75
Rochester	112.50	19.25
Cleveland	101.35	18.00
Philadelphia	122.85	21.00
Pittsburgh	107.10	18.75

The railroad fares given above are for round trips, forty-five day limits. Arrangements can be made with the railroads to take different routes going and coming, if so desired, but once the choice is made it must be adhered to, as changes in the itinerary may be effected only with considerable difficulty and formality.

New streamlined trains will be operating from Chicago to Los Angeles and San Francisco, making the trip to Los Angeles in 39 hours. A special fare is levied on these trains.

Plans for the Convention are already under way. The Papers Committee, under the Chairmanship of Mr. G. E. Matthews, and directed by Mr. J. I. Crabtree, *Editorial Vice-President*, are already engaged in soliciting an outstanding group of technical papers and presentations. The Officers and Board of Managers of the West Coast Section, Mr. G. F. Rackett, *Chairman*, are collaborating with Mr. W. C. Kunzmann, *Convention Vice-President*, in arranging the various facilities of the Convention.

The usual Semi-Annual Banquet will be held, and arrangements are being made for visits to studios and to other points of interest in and about Hollywood. Details of the program will be announced later, but in the meantime members are urged to make their plans early for attending the Convention, and it is suggested that they may perhaps combine their vacation periods with the trip.

ADMISSIONS COMMITTEE

At a recent meeting of the Admissions Committee, at the General Office of the Society, the following applicants for membership were admitted to the Associate grade:

ATHEY, T. D.
c/o William Adams & Co., Ltd.
Clarance St.
Sydney, N. S. W.
Australia

CRUSE, A. W.
1901 Wyoming Ave., N. W.
Washington, D. C.

DONNE, C. W.
Box 877 G. P. O.
Melbourne, Victoria
Australia

FISHER, R. J.
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Rochester, N. Y.

FRANKEL, S.
1588 E. 14th St.
Brooklyn, N. Y.

FURSE, B. W.
Wingello House
Angel Place
Sydney, N. S. W.
Australia

GANTZ, H. C.
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Chicago, Ill.

GESSIN, M.
267 Lincoln Place
Brooklyn, N. Y.

GILLE, H. E.
149 Congress St.
Jersey City, N. J.

HAMMOND, J. A.
30 E. 42d St.
New York, N. Y.

HANDSCOMBE, H. D.
RCA Victor Argentina
Calle Bartolome Mitre 1976
Buenos Aires, Argentina

HOWITT, G. W.
48 Grover St.
Rochester, N. Y.

INGRAM, W. H.
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North Bloomfield, N. Y.

KELLOGG, P.
208 Fernow Hall
Cornell University
Ithaca, N. Y.

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Wien XVIII
Vienna, Austria

LANE, H. M.
350 Lake St.
Belmont, Mass.

LEAHY, W.
6372 Santa Monica Blvd.
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610 Olive St.
St. Louis, Mo.

MILLER, E. K.
234 Miami Ave.
Sidney, Ohio

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115 Broadway
New York, N. Y.

NORTON, B.
423 64th St.
Brooklyn, N. Y.

NYE, H.
3135 Hollycrest Drive
Hollywood, Calif.

PADELFORD, M.
285 N. San Rafael Ave.
Pasadena, Calif.

PETERSON, E. A., II
601 Queen St.
Alexandria, Virginia

PHILLIPS, F. R.
96 Chestnut Drive
Sale, Cheshire, England

PHILLIPS, L.
133 Meadow St.
New Haven, Conn.
PURDY, R. G.
Eastman Kodak Co.
Research Laboratories
Rochester, N. Y.

REISS, M.
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Washington, D. C.

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Sarmiento 2174
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Los Angeles, Calif.
SZABO, J.
525 E. 82d St.
New York, N. Y.

TELEWSKI, F.
6 Buckingham Road
Palisade, N. J.

THATCHER, L. P.
216 Close Ave.
Toronto, Canada
TOLER, J. H.
332 S. Michigan Ave.
Chicago, Ill.

VACHA, S. B.
Bombay Talkies
Malad, Bombay
India
VERMEULEN, R.
N. V. Philips' Gloelimapenfabrieken
Eindhoven, Holland

WALTON, E. C.
206 E. 40th St.
New York, N. Y.
WEISS, M. L.
60 Lithgow St.
Dorchester, Mass.
WELSH, S.
2327 Winnemac Ave.
Chicago, Ill.
WILLIAMS, C. S.
115 Third St., S. W.
Waverly, Iowa

The Society regrets to announce the death of

NORMAN M. LAPORTE

August 9, 1936

JOURNAL

OF THE SOCIETY OF

MOTION PICTURE ENGINEERS

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